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Langley Atmospheric Information Retrieval System (LAIRS)

System Description and User's Guide

D. E. Boland, Jr., and Taesul Lee

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TABLE OF CONTENTS

TABLE OF CONTENTS (Cont'd)

LIST OF ILLUSTRATIONS

Figure

LIST OF TABLES

Table

SECTION 1 - INTRODUCTION

The primary objective of the Langley Atmospheric Information Retrieval Ssytem (LAIRS) is to make it possible to obtain accurate estimates of atmospheric pressure, density, temperature, and winds along the Shuttle reentry trajectory for use in postflight data reduction. One possible application of this information will be in the Aerodynamic Coefficient Measurement Experiment (ACME), which is part of the Shuttle Flight Test Program. The objective of this experiment is to improve estimates of the aerodynamic coefficients characterizing the Shuttle.

The LAIRS Program operates in one of two basic modes, default or adjusted. In the default mode, pressure, density, temperature, and wind values are interpolated for specified points along a Shuttle reentry trajectory using standard (default) atmospheric models stored in the computer. In the adjusted mode, atmospheric modeling parameters are adjusted to fit in situ measurements of atmospheric quantities from various sources, such as sounding rockets, balloons, or ground instrumentation. Several modeling approaches are available when LAIRS is operating in the adjusted mode, including the Jacchia-Roberts model for the upper atmosphere and both linear and nonlinear least squares polynomial fitting models for the lower atmosphere. These models are discussed in detail in this document.

The purpose of this document is to describe the LAIRS Program and its operation. Section 2 presents the User's Guide, including descriptions of all input and output. Section 3 describes the overall system and includes subroutine descriptions for all of the LAIRS subroutines. Section 4 contains descriptions of the computational models used to determine the required atmospheric parameters, and

Section 5 describes the development of an optimal procedure for using the LAIRS Program with data from the first Shuttle flight (STS-1). Appendix A contains descriptions of the COMMON blocks, Appendix B specifies the formats of the files that are created and used by the LAIRS Program, and Appendix C contains benchmark decks used for testing the LAIRS Program. File maintenance routines are described in Appendix D, and the results of noise analysis experiments with the LAIRS Program are discussed in Appendix E.

The authors wish to acknowledge the assistance and guidance of Joseph M. Price, Robert C. Blanchard, and Harold R. Compton of the NASA Langley Research Center, who contributed much to the successful development and implementation of the LAIRS Program. They also wish to acknowledge the extensive contributions to this document by Ajay K. Kapoor, Richard A. Kuseski, and James O. Cappellari, Jr., of CSC.

SECTION 2 - USER'S GUIDE

The Langley Atmospheric Information Retrieval System (LAIRS) Program has been implemented on the Langley Research Center (LaRC) CDC Cyber 170 computer with the NOS 1.4 operating system. This section contains a description of the input required (both user input and data), the output options and reports, and the output files for the LAIRS Program. In these descriptions, it is assumed that the reader has a working knowledge of the computer and the operating system.

2.1 USER INPUT

The user input for the LAIRS Program is composed of the following three types of input:

- ENTREE Trajectory File - This file contains Shuttle positions as a function of time along with the uncertainties associated with those positions.
- Meteorological Data Files - These files contain observations of temperature, pressure, density, and winds made at up to three stations along the Shuttle reentry path.
- Formatted Keyword Cards - The information on these cards will include the following:
  - Atmospheric model to be used
  - Type of profile to be calculated (ENTREE Program trajectory, Local Atmospheric Profile, or both)

In addition, a previously created permanent file (KP) containing the 3-hour geomagnetic indices (K_p) and the daily Ottawa 10.7-centimeter solar flux values is needed for use with the Jacchia-Roberts density model, which represents the upper portion of the atmosphere in the LAIRS Program.

2.1.1 ENTREE TRAJECTORY

The LAIRS input trajectory data is a standard LaRC Best Estimate Trajectory (BET) file, output by the ENTREE Program. The BET file gives Shuttle altitude, latitude, and longitude, as well as the uncertainties in these parameters, as a function of time.

2.1.2 METEOROLOGICAL DATA FILES

The LAIRS Program can accept up to three meteorological data files, each containing a vertical profile of atmospheric parameters measured at a given station. These files may be created by a preprocessor (PREMET) from a meteorological data tape supplied by the National Oceanic and Atmospheric Administration (NOAA). Table 2-1 shows the format of this tape; more information on the preprocessor and the files it creates is given in Appendix B. These files may also be created from raw data supplied to LaRC by NOAA, the Air Force, or other sources.

2.1.3 KEYWORD CARD DESCRIPTIONS

All of the LAIRS Program input, with the exception of the permanent, working, and meteorological files, is provided via keyword cards. Each keyword card includes an alphanumeric identifier in card columns 1-10. This identifier is called the keyword. This section describes each keyword card, its use, and the information that must be supplied on it.

The keyword card listing is alphabetical, and the name of the keyword appears in the upper right-hand or left-hand corner of the page for quick reference. The keywords conform to a format that is described on each keyword page. In all cases, this format consists of one alphanumeric field (A10) and seven real fields (7F10.3). Data supplied in the seven real fields will be accepted by LAIRS as single-precision numerical data and must be expressed as a valid

(text continues on page 2-23)

Table 2-1. Format of LAIRS Meteorological Data Tape (1 of 2)[1]

WORD	SYMBOL	DESCRIPTION	UNITS
1	LAT	Latitude	Degrees, + N
2	LON	Longitude	Degrees, + E to 360
3	FLAG	Data flag: = 0, measured data = 1, modeled data = 2, combined measured and modeled data	
4	--	Spare	
5	ALT	Geometric altitude	Feet
6	WS	Horizontal wind speed	Feet/second
7	WD	Direction horizontal wind is coming from relative to true north, north being 0 degrees, increasing positively clockwise	Degrees
8	TE	Ambient temperature	Degrees C
9	PR	Ambient pressure	Millibars
10	D	Ambient density	Grams/meter^3
11	DW	Dew point (not used)	Degrees C
12	TEU	Ambient temperature systematic uncertainty	Degrees C
13	PRU	Ambient pressure systematic uncertainty	Millibars
14	DU	Ambient density systematic uncertainty	Grams/meter^3
15	HWSUS	Horizontal wind speed systematic uncertainty	Feet/second
16	HWSUN	Horizontal wind speed noise or fluctuation uncertainty	Feet/second

[1]All quantities are real variables that are one word in length.

Table 2-1. Format of LAIRS Meteorological Data Tape (2 of 2)

WORD	SYMBOL	DESCRIPTION	UNITS
17	VWSUN	Vertical wind speed noise or fluctuation uncertainty	Feet/second
18	HWDUS	Horizontal wind direction systematic uncertainty	Degrees
19	HWDUN	Horizontal wind direction noise or fluctuation uncertainty	Degrees
20		Spare	--

CREATE

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	CREATE - Keyword to create a new file in standard LAIRS meteorological file format from the output USE file. Default (no CREATE card) is to omit creation of this file.
11-81	7F10.3	Blank

DC

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	DC - Keyword to perform differential corrections on atmospheric data
11-20	F10.3	Blank
21-30	F10.3	Use temperature data in differential correction: = 0., yes (default) = 1., no
31-40	F10.3	Use pressure data in differential correction: = 0., yes (default) = 1., no
41-50	F10.3	Use density data in differential correction: = 0., yes (default) = 1., no
51-60	F10.3	Blank
61-70	F10.3	Polynomial segment number for this DC card:* = 0., this card applies to all segments (default) = 1., top segment (65-90 kilometers) = 2., middle segment (25-65 kilometers) = 3., bottom segment (0-25 kilometers)
71-80	F10.3	Continuity with next segment imposed at upper segment boundary: = 0., yes (default) = 1., no

*Up to three DC keyword cards (one for each segment) may be included in the deck.

DCEDIT

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	DCEDIT - Keyword to set edit criteria for defferential corrections
11-20	F10.3	Blank
21-30	F10.3	RMS multiplier (default = 3.0)
31-40	F10.3	Initial value of RMS (default = 10.E10)
41-50	F10.3	RMS adder parameter (default = 0.0)
51-60	F10.3	A priori temperature uncertainty (default = 5 percent)
61-70	F10.3	A priori pressure uncertainty (default = 5 percent)
71-80	F10.3	A priori density uncertainty (default = 5 percent)

NOTE: Any observation for which the absolute value of the weighted (O-C) is larger than the quantity (weighted RMS x RMS multiplier + RMS adder) is edited out. The weighted RMS used is obtained from the previous iteration (the initial value of RMS is used for the first iteration).

DCITER

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	DCITER - Keyword to set DC iteration flags
11-20	F10.3	Blank
21-30	F10.3	Maximum number of iterations
31-40	F10.3	Convergence criterion
41-80	4F10.3	Blank

DEBUG

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	DEBUG - Keyword to obtain debug printout
11-20	F10.3	Blank
21-30	F10.3	Debug type: = 1., overall flow debug = 2., working file listing = 3., parameter calculation debug = 4., BET file listing = 5., created meteorological file listing (to be used with CREATE card) = 8., translational coefficient adjustment debug = 9., meteorological file listing (to be used in a polynomial model run) = 10., differential correction debug = 15., onboard measurement calculation debug
31-80	5F10.3	Blank

DERIVE

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	DERIVE - Keyword to override pressure and density calculation with derivation of pressure and density from temperature via physical relationships
11-20	F10.3	Blank
21-30	F10.3	Integration step size (kilometers)
31-40	F10.3	Source of pressure boundary condition: = 0., this card = 1., default file = 2., meteorological profile
41-50	F10.3	Reference altitude (kilometers)
51-60	F10.3	Pressure at the reference altitude (newtons/meter^2)
61-80	2F10.3	Blank

END

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	END - Keyword to specify end of keyword card deck
11-80	7F10.3	Blank

ENTREE

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	ENTREE - Keyword to set ENTREE profile type (along Shuttle reentry path)
11-20	F10.3	YYMMDD. of first point on input BET file (date of Shuttle re-entry)
21-30	F10.3	Interval (in number of points) at which BET file will be sampled (default = 1., i.e., read each point)
31-40	F10.3	Lower altitude limit for BET file processing (kilometers) (default = bottom of BET file)
41-50	F10.3	Upper altitude limit for BET file processing (kilometers) (default = top of BET file)
51-70	2F10.3	Blank
71-80	F10.3	Run identification number

FIN

- Card format: A10, 7F10.3

- Detailed format:

Columns	Format	Description
1-10	A10	FIN - Keyword following last stacked deck. This keyword terminates the run.
11-80	7F10.3	Blank

INTERPOL

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	INTERPOL - Keyword to set interpolator type
11-20	F10.3	Blank
21-30	F10.3	Vertical interpolator type: = 1., first-order Lagrange = 2., second-order Lagrange
31-40	F10.3	Horizontal interpolator type: = 0., first-order interpolation in horizontal distance from profile = 1., first-order bivariate interpolation in latitude and local solar time = 2., second-order bivariate interpolation in latitude and solar time
41-80	4F10.3	Blank

LAP

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	LAP - Keyword to set Local Atmospheric Profile type
11-20	F10.3	YYMMDD. for LAP
21-30	F10.3	HHMMSS.SS for LAP (GMT)
31-40	F10.3	Latitude for LAP (decimal degrees)
41-50	F10.3	Longitude for LAP (decimal degrees)
51-60	F10.3	Lower altitude for LAP (kilometers)
61-70	F10.3	Upper altitude for LAP (kilometers)
71-80	F10.3	Altitude interval for LAP (kilometers)

LOWMOD

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	LOWMOD - Keyword to set model options for lower atmosphere
11-20	F10.3	Blank
21-30	F10.3	Atmospheric model type: = 1., interpolate T, P, and D from default files (default) = 2., interpolate T, P, and D from meteorological profiles = 3., calculate T, P, and D from default polynomial model = 4., calculate T, P, and D from adjusted polynomial model
31-40	F10.3	Wind model type:* = 0., none (default) = 1., interpolate from default file = 2., interpolate from meteorological profiles = 3., calculate from analytical model
41-50	F10.3	Include latitude variations: = 0., no (default) = 1., yes
51-60	F10.3	Include diurnal and semidiurnal variations: = 0., no (default) = 1., yes
61-70	F10.3	Include weighting in adjusted polynomial model: = 0., no (default) = 1., yes

*Wind model choice is applicable only to atmospheric model types 3 and 4. Types 1 and 2 automatically return interpolated wind values (unless wind type 0 is chosen).

LOWMOD (Cont'd)

Columns	Format	Description
71-80	F10.3	Recalculate final temperature to agree with gas law: = 0., yes (default) = 1., no

MODBOUND

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	MODBOUND - Keyword to set boundaries of atmospheric model segments
11-20	F10.3	Blank
21-30	F10.3	Boundary between first and second segments (kilometers) (default = 90 kilometers)
31-40	F10.3	Boundary between second and third segments (kilometers) (default = 65 kilometers)
41-50	F10.3	Boundary between third and fourth segments (kilometers) (default = 25 kilometers)
51-80	3F10.3	Blank

MODREF

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	MODREF - Keyword to set model reference values
11-20	F10.3	Blank
21-30	F10.3	Model reference latitude (degrees)
31-40	F10.3	Model reference local solar time (decimal hours)
41-80	4F10.3	Blank

PRINTALL

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	PRINTALL - Keyword to print all polynomial fitting residual reports in addition to the standard reports. Default (no PRINTALL card) is to print only the standard reports.
11-80	7F10.3	Blank

TRANADJ

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	TRANADJ - Keyword to invoke adjustment of translational coefficients
11-20	F10.3	Blank
21-30	F10,3	Diurnal/semidiurnal coefficient adjustment = 0., no (default) = 1., yes
31-40	F10.3	Latitude gradient adjustment = 0., no (default) = 1., yes
41-80	410.3	Blank

UPMOD

- Card format: A10, 7F10.3
- Detailed format:

Columns	Format	Description
1-10	A10	UPMOD - Keyword to set model options for upper atmosphere
11-20	F10.3	Blank
21-30	F10.3	Atmospheric model type: = 1., interpolate T, P, and D from default files (default) = 2., interpolate T, P, and D from meteorological profiles = 3., calculate T, P, and D from default Jacchia-Roberts model = 4., calculate T, P, and D from adjusted Jacchia-Roberts model
31-40	F10.3	Wind model type* = 0., none (default) = 1., interpolate from default file = 2., interpolate from meteorological profiles
41-50	F10.3	Include latitude variations** = 0., no (default) = 1., yes
51-60	F10.3	Include diurnal and semidiurnal** variations = 0., no (default) = 1., yes
61-80	2F10.3	Blank

*Wind model choice is applicable to atmospheric model types 3 and 4 only. Types 1 and 2 automatically return interpolated wind.

**Latitude and diurnal/semidiurnal variations are automatically included in the Jacchia-Roberts atmospheric models, types 2 and 4.

floating point representation (i.e., either a number punched within the field containing a decimal point or a number punched with an E decimal exponent right-justified in the field). Any data value supplied for the real fields (even though the data may be a whole number) must be a floating point representation.

The keyword descriptions state the default data values where appropriate. A default value will be used if the data field is left blank or if a value of zero is supplied in the field. Any value in the field other than zero or blank will override a specified default.

The data units used (unless otherwise specified) are meters, seconds, meters/second, and degrees. Units for most quantities are standard M.K.S. units. Dates supplied on LAIRS input cards are usually words in the packed form:

yymmdd

hhmmss.ss

2.2 OUTPUT REPORTS

The output reports for the LAIRS Program consist of several separate reports. These include the LAIRS Initialization Reports, the File Statistics Report, the Polynomial Fitting Reports, the Atmospheric Parameters Output Report, and the Summary Report. Each report will be explained in more detail later. Briefly, the output reports perform the following functions:

1. Initialization Reports - The first of these reports shows the input keyword card images. This report is followed by the Initial Conditions Report for the lower and upper atmosphere models, which includes a description of the output parameters.

2. File Statistics Report - This report summarizes the features of the working file or the meteorological files that are the source of data for this LAIRS run.

3. Polynomial Fitting Reports - These reports detail aspects of the polynomial fitting (both linear and nonlinear) such as observations, residuals, weighting factors, and calculated coefficients.

4. Atmospheric Parameters Output Report - This report consists of a block printout in tabular form of all the output parameters for each trajectory point as a function of altitude.

5. Error Summary Report - This report lists any errors that were encountered during the LAIRS run.

2.2.1 INITIALIZATION REPORTS

The first page of the printed output lists the input data keyword cards for verification (see Figure 2-1).

The second page of output is the Initial Conditions Report (Figure 2-2). This report contains a description of the run as specified by the control parameters. The type of profile is reported along with the epoch of the run. The lower and upper atmosphere parameters are specified, including the type of atmosphere and wind models, the variations desired, and the interpolation type.

The last pages of the report contain a description of the output parameters (see Figures 2-3 and 2-4). This includes the title, the units, and a description of each parameter that will be output in the Atmospheric Parameters Output Report.

LAIRS KEYWORD CARD IMAGES

ENTREE	810414.0000	10.0000	60.0000	95.0000	0.0000	0.000
UPMOD	0.0000	3.0000	2.0000	1.0000	1.0000	0.000
LOWMOD	0.0000	4.0000	2.0000	1.0000	1.0000	0.000
MODBOUND	0.0000	90.0000	68.0000	14.0000	4.0000	0.000
INTERPOL	0.0000	2.0000	0.0000	0.0000	0.0000	0.000
DC	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
PRINTALL	0.0000	0.0000	0.0000	0.0000	0.0000	0.000
STATION	0.0000	17.0830	0.0000	0.0000	0.0000	0.000
STATION	0.0000	17.2167	0.0000	0.0000	0.0000	0.000
STATION	0.0000	18.3670	0.0000	0.0000	0.0000	0.000
END	0.0000	0.0000	0.0000	0.0000	0.0000	0.000

Figure 2-1. LAIRS Keyword Card Images

LANGLEY ATMOSPHERIC INFORMATION RETRIEVAL SYSTEM

INITIAL CONDITIONS REPORT

EPOCH =810414 174230.000   PROFILE IS ENTREE   ID NUMBER =   0

LOWER ATMOSPHERE MODEL	UPPER ATMOSPHERE MODEL
TYPE = ADJUSTED POLYNOMIAL	TYPE = JACCHIA-ROBERTS
WIND MODEL = METEOROLOGICAL INTERPOL.	WIND MODEL = METEOROLOGICAL INTERPOL.
LAT. VARIATIONS INCLUDED - YES	LAT. VARIATIONS INCLUDED - YES
D/SD VARIATIONS INCLUDED - YES	D/SD VARIATIONS INCLUDED - YES

ALTITUDE INTERPOLATION USED - 2ND ORDER LAGRANGE

METEOROLOGICAL INTERPOLATION USED - 1ST ORDER UNIVARIATE

DIFFERENTIAL CORRECTION APPLIED - YES

DERIVE PRESSURE AND DENSITY FROM TEMPERATURE - NO

RECOMPUTE TEMPERATURE FROM GAS LAW - NO

Figure 2-2. Initial Conditions Report

DESCRIPTION OF OUTPUT PARAMETERS - PART I

TITLE	UNITS	DESCRIPTION
ALT	KM	ALTITUDE
LAT	DECIMAL DEG	LATITUDE
LONG	DECIMAL DEG	LONGITUDE
GMTSEC	DECIMAL SEC (TIME)	GMT IN SECONDS
LST	DECIMAL HOURS	LOCAL SOLAR TIME
TEMP	DEG KELVIN	ATMOSPHERIC TEMPERATURE
PRESSURE	N/M**2	ATMOSPHERIC PRESSURE
DENSITY	KG/M**3	ATMOSPHERIC DENSITY
WNDSP	M/SEC	WIND SPEED
WNDDR	DEG FROM N	WIND DIRECTION
TEMPU	DEG KELVIN	UNCERTAINTY IN TEMPERATURE
PRESU	N/M**2	UNCERTAINTY IN PRESSURE
DENU	KG/M**3	UNCERTAINTY IN DENSITY
WSU	M/SEC	UNCERTAINTY IN WIND SPEED
WDU	DECIMAL DEG	UNCERTAINTY IN WIND DIRECTION

Figure 2-3. Description of Output Parameters (Part 1)

DESCRIPTION OF OUTPUT PARAMETERS - PART II

TITLE	UNITS	DESCRIPTION
ALT	KM	ALTITUDE
GMTSEC	DECIMAL SEC.(TIME)	GMT IN SECONDS
M.WT	GM/MOLE	MEAN NOLECULAR WEIGHT
SC.HT	KM	PRESSURE SCALE HEIGHT
MACH NO	SPEED OF SOUND	VELOCITY(MACH NUMBER)
PN	N/M**2	ONBOARD PRESSURE
PCDEV	PERCENT	PERCENT DEVIATION FROM GAS LAW
E-W WD	M/SEC	EAST-WEST WIND COMPONENT
N-S WD	M/SEC	NORTH-SOUTH WIND COMPONENT
ALTU	KM	UNCERTAINTY IN ALTITUDE
LATU	DECIMAL DEG	UNCERTAINTY IN LATITUDE
LONU	DECIMAL DEG	UNCERTAINTY IN LONGITUDE
E-W U	M/SEC	EAST-WEST WIND UNCERTAINTIES
N-S U	M/SEC	NORTH-SOUTH WIND UNCERTAINTIES

Figure 2-4. Description of Output Parameters (Part 2)

2.2.2 FILE STATISTICS REPORT

This report shows the latitude and longitude of each meteorological station supplying data for the run, as well as the number of observations and the altitude limits on the files provided by each station (see Figure 2-5). Also shown are the atmospheric segment boundaries and the temperature and density at the top boundary, which are used by the Jacchia-Roberts model and by the differential correction polynomial model. The value ZREF, which is the reference altitude supplied by the user for the (optional) pressure and density override integration from temperature, is given, together with the pressure at that altitude.

If the default model is used for atmospheric parameter calculation, the above information will be taken from the default file.

2.2.3 POLYNOMIAL FITTING REPORTS

The exact nature of the polynomial fitting reports will depend on whether the user has selected a simple, linear fit to the meteorological data or has selected the nonlinear differential correction process. As the latter possibility includes all the reports that would appear in the former, the reports illustrated here are those that a user would see when selecting the differential correction option.

The first report (see Figure 2-6) shows the result of the initial fit to temperature data which establishes the default coefficients for the differential correction process (this report is printed segment by segment; only the report for the upper segment is shown here). The temperature observations for each altitude point on each file are tabulated, along with the computed value at that point and the residual. Because no uncertainties were provided for this sample data,

```
                    FILE STATISTICS REPORT
              SOURCE OF DATA: METEOROLOGICAL FILES
       STATION NO.  1    LONGITUDE 200.20    LATITUDE 22.00
             31 POINTS BETWEEN  58.00 KM AND  92.00 KM
       STATION NO.  2    LONGITUDE 240.90    LATITUDE 34.10
             35 POINTS BETWEEN  23.32 KM AND  67.25 KM
       STATION NO.  3    LONGITUDE 242.27    LATITUDE 34.98
            100 POINTS BETWEEN    .72 KM AND  30.78 KM
ATMOSPHERIC SEGMENT BOUNDARIES (KM) : BOUND1 =  90.00      BOUND2 =  68.00       BOUND3 =  14.00
                             T(BOUND1) =    191.000 DEGREES
                             D(BOUND1) =   .326E-05 KG/M**3
                                  ZREF =     30.000 KM
                               P(ZREF) =   .113E+04 N/M**2
```

Figure 2-5. File Statistics Report

LAIRS POLYNOMIAL FITTING REPORT

ITERATION NUMBER 0

UPPER SEGMENT

ALTITUDE (KM)	OBS TYPE	OBSERVED O	COMPUTED C	RESIDUAL O-C	UNCERTAINTY DEL O	OBSERVED LOG O	COMPUTED LOG C	WEIGHTED RESIDUAL	WEIGHT	EDIT FLAG
92.00	TEMP	189.0	189.6	-.6060	0.			-.6413E-01	.1058	1
91.00	TEMP	191.0	189.1	1.893	0.			.1982	.1047	1
90.00	TEMP	191.0	188.8	2.236	0.			.2342	.1047	1
85.00	TEMP	189.2	189.5	-.2895	0.			-.3063E-01	.1058	1
84.00	TEMP	185.1	190.1	-5.040	0.			-.5479	.1087	1
83.00	TEMP	185.0	190.9	-5.917	0.			-.6466	.1093	1
82.00	TEMP	188.0	191.9	-3.934	0.			-.4252	.1081	1
81.00	TEMP	193.0	193.1	-.1067	0.			-.1129E-01	.1058	1
80.00	TEMP	197.0	194.4	2.547	0.			.2653	.1042	1
79.00	TEMP	199.0	196.0	3.023	0.			.3133	.1036	1
78.00	TEMP	201.0	197.7	3.317	0.			.3419	.1031	1
77.00	TEMP	205.0	199.6	5.424	0.			.5506	.1015	1
76.00	TEMP	206.0	201.7	4.340	0.			.4406	.1015	1
75.00	TEMP	208.0	203.9	4.061	0.			.4102	.1010	1
74.00	TEMP	209.3	206.4	2.931	0.			.2945	.1005	1
73.00	TEMP	210.7	209.1	1.601	0.			.1601	.1000E+00	1
72.00	TEMP	210.0	212.0	-1.930	0.			-.1940	.1005	1
71.00	TEMP	212.4	215.0	-2.668	0.			-.2654	.9950E-01	1
70.00	TEMP	213.7	218.3	-4.614	0.			-.4568	.9901E-01	1
69.00	TEMP	215.0	221.8	-6.852	0.			-.6751	.9852E-01	1
68.00	TEMP	216.2	225.5	-9.306	0.			-.9123	.9804E-01	1
67.00	TEMP	221.4	229.4	-7.979	0.			-.7635	.9569E-01	1
66.00	TEMP	232.7	233.5	-.8732	0.			-.7938E-01	.9091E-01	1
65.00	TEMP	244.9	237.9	7.007	0.			.6040	.8621E-01	1
67.25	TEMP	242.8	228.4	14.34	0.			1.199	.8359E-01	1
64.53	TEMP	245.0	240.0	4.954	0.			.4117	.8310E-01	1

WEIGHTED RMS FOR THIS ITERATION= .49909279
TOTAL NUMBER OF POINTS = 26

Figure 2-6. LAIRS Polynomial Fitting Report an a priori uncertainty of 5 percent (which can be changed by the user) was used for all parameters. It is necessary to provide uncertainties in order to balance the contributions that each of the parameters makes to the fit. As no logarithms are used in the initial temperature fit, the columns for LOG O and LOG C are blank. The edit flag indicates whether an observation has been edited out. An edit flag of 1 means that the observation has been used; a flag of zero means that it has been edited. At the bottom of the report are the weighted root mean square of the residuals and the total number of points used in the fit.

The second residual report (Figure 2-7) is output during the differential correction process. It is identical in format to the first report, except that, for pressure and density, the logarithms of the observed and computed values (which are the actual subjects of the fitting process) are displayed. The weights and weighted residuals are also expressed in log space.

The report shown in Figure 2-8 follows these residual reports for each segment and for each iteration. The number of data points available in this segment and the number of points used (i.e., not edited) are given, as are the values of the current, previous, and predicted root mean squares of the residuals. A summary of the current status of the solve-for parameters is also presented.

In a differential correction run, the variance-covariance matrix of the solve-for parameters is computed in each iteration and printed out at the end of the iteration (see Figure 2-9). The diagonal elements of this matrix define the variances of the solve-for parameters, and the off-diagonal elements are used to compute correlation coefficients between two different solve-for parameters. The square root of the variance of a solve-for parameter gives the standard

LAIRS NON LINEAR LEAST SQUARES ESTIMATION REPORT

ITERATION NUMBER 3

UPPER SEGMENT

ALTITUDE (KM)	OBS TYPE	OBSERVED O	COMPUTED C	RESIDUAL O-C	UNCERTAINTY DEL O	OBSERVED LOG O	COMPUTED LOG C	WEIGHTED RESIDUAL	WEIGHT	EDIT FLAG
92.00	PRES	.1270	.1315	-.4512E-02	0.	-2.064	-2.029	-.7155	20.50	1
91.00	PRES	.1510	.1567	-.5739E-02	0.	-1.890	-1.853	-.7646	20.50	1
90.00	PRES	.1790	.1872	-.8219E-02	0.	-1.720	-1.675	-.9201	20.50	1
85.00	PRES	.4783	.4638	.1449E-01	0.	-.7375	-.7683	.6307	20.50	1
84.00	PRES	.5802	.5566	.2357E-01	0.	-.5444	-.5859	.8502	20.50	1
83.00	PRES	.6993	.6676	.3168E-01	0.	-.3577	-.4041	.9501	20.50	1
82.00	PRES	.8383	.8000	.3830E-01	0.	-.1764	-.2231	.9585	20.50	1
81.00	PRES	.9990	.9576	.4144E-01	0.	-.1008E-02	-.4337E-01	.8683	20.50	1
80.00	PRES	1.183	1.145	.3853E-01	0.	.1681	.1350	.6787	20.50	1
79.00	PRES	1.406	1.366	.4020E-01	0.	.3407	.3117	.5946	20.50	1
78.00	PRES	1.662	1.627	.3539E-01	0.	.5080	.4865	.4411	20.50	1
77.00	PRES	1.958	1.934	.2479E-01	0.	.6721	.6594	.2612	20.50	1
76.00	PRES	2.300	2.293	.6337E-02	0.	.8328	.8301	.5655E-01	20.50	1
75.00	PRES	2.697	2.714	-.1696E-01	0.	.9923	.9985	-.1285	20.50	1
74.00	PRES	3.168	3.205	-.3723E-01	0.	1.153	1.165	-.2395	20.50	1
73.00	PRES	3.716	3.775	-.5921E-01	0.	1.313	1.328	-.3240	20.50	1
72.00	PRES	4.351	4.436	-.8509E-01	0.	1.470	1.490	-.3969	20.50	1
71.00	PRES	5.097	5.201	-.1044	0.	1.629	1.649	-.4154	20.50	1
70.00	PRES	5.939	6.083	-.1440	0.	1.781	1.805	-.4910	20.50	1
69.00	PRES	6.998	7.097	-.9958E-01	0.	1.946	1.960	-.2896	20.50	1
68.00	PRES	8.190	8.262	-.7255E-01	0.	2.103	2.112	-.1808	20.50	1
67.00	PRES	9.547	9.597	-.4942E-01	0.	2.256	2.261	-.1058	20.50	1
66.00	PRES	11.09	11.12	-.2803E-01	0.	2.406	2.409	-.5173E-01	20.50	1
65.00	PRES	12.79	12.86	-.7782E-01	0.	2.548	2.554	-.1244	20.50	1
67.25	PRES	9.179	9.243	-.6419E-01	0.	2.217	2.224	-.1428	20.50	1
64.53	PRES	13.30	13.77	-.4683	0.	2.588	2.622	-.7092	20.50	1

Figure 2-7. LAIRS Nonlinear Least Squares Estimation Report(Part 1)

LAIRS NON LINEAR LEAST SQUARES ESTIMATION REPORT

ITERATION NUMBER 3

UPPER SEGMENT

DC HAS CONVERGED

	AVAILABLE	USED
NUMBER OF TEMPERATURE DATA	26	26
NUMBER OF DENSITY DATA	26	26
NUMBER OF PRESSURE DATA	26	26
CURRENT WEIGHTED RMS	.69619249	
PREVIOUS WEIGHTED RMS	.69753787	
PREDICTED WEIGHTED RMS	.69619348	

TEMP WRMS = .72058210 PRES WRMS = .55948992 DENS WRMS = .78853309

SOLVE-FOR PARAMETER REPORT

	APRIORI VALUE	CURRENT VALUE	CORRECTION CURRENT-PREVIOUS
TEMP COEFF A0	188.76371	185.91303	-.20062635
TEMP COEFF A1	-.26482847	-1.8133701	.36539087E-01
TEMP COEFF A2	.78974132E-01	.23398251	-.85495997E-03
TEMP COEFF A3	.40869166E-03	-.35267601E-02	-.94541438E-05
LOG PRES	-1.5906200	-1.6754745	-.23142881E-02

Figure 2-8. LAIRS Nonlinear Least Squares Estimation Report (Part 2)

COVARIANCE MATRIX AND CORRELATION COEFFICIENTS

	A1	A2	A3	A0	LOG PRES
A1	.168583E+01	-.135638E+00	.313935E-02	-.539155E+01	-.683610E-02
A2	-.961177E+00	.118125E-01	-.286776E-03	.365611E+00	.169390E-03
A3	.902397E+00	-.984773E+00	.717912E-05	-.762422E-02	-.290209E-07
A0	-.849936E+00	.688537E+00	-.582424E+00	.238694E+02	.687183E-01
LOG PRES	-.249686E+00	.739109E-01	-.513650E-03	.667027E+00	.444648E-03

	TEMPERATURE	PRESSURE	DENSITY
WEIGHTED ROOT MEAN SQUARE	.62743467	1.0350223	.98876449
AVERAGE WEIGHTED RESIDUALS	.12560247	-.10205341	.10205172
STANDARD DEV. OF WEIGHTED RESIDUALS	.61473432	1.0299788	.98348394

Figure 2-9. Covariance Matrix and Correlation Coefficients Report

deviation of the solve-for parameter. The upper triangular part (including the diagonal elements) of the matrix printed out represents the variance-covariance matrix and the lower triangular part represents the correlation coefficients.

When the differential correction process is completed, an Estimation Summary Report (see Figure 2-10) is produced. This report displays the calculated temperature coefficients for each segment and the boundary value of pressure at the top of each segment.

2.2.4 ATMOSPHERIC PARAMETERS OUTPUT REPORT

This report, which is divided into two parts, provides tables of all the output parameters for each trajectory point (see Figures 2-11 and 2-12). In addition to the given (ENTREE) information regarding altitude, latitude, longitude, and time (GMT seconds), Part I of the report prints the value of local solar time (solar hour angle, measured from zero hours at noon) and the calculated values for temperature, pressure, density, wind speed, and wind direction. Also printed are the uncertainties in all the calculated parameters except local solar time. Part II of the report lists the mean molecular weight used in calculating the parameters and the calculated values of pressure scale height, Mach number, onboard pressure measurement, and the east-west and north-south wind components. The percent deviation from the gas law of the calculated values of temperature, pressure, and density is reported, although this deviation is removed in the final reported parameters (the percent deviation serves as a lower estimate on the error inherent in the LAIRS processing). Part II of the report also gives the uncertainty in the input trajectory point and in the Cartesian wind components and repeats the altitude and time values as an index.

LAIRS NON LINEAR LEAST SQUARES

ESTIMATION SUMMARY REPORT

	UPPER SEGMENT	MIDDLE SEGMENT
TEMP COEFF A0	185.90976	221.52518
TEMP COEFF A1	-1.8151987	6.6014731
TEMP COEFF A2	.23430978	-.26004440
TEMP COEFF A3	-.35552341E-02	.24965560E-02
PRESSURE AT TOP BOUNDARY	-1.6754178	2.1125525

```
JACCHIA-ROBERTS BOUNDARY VALUES READJUSTED TO MATCH POLYNOMIAL MODEL:
NEW TEMPERATURE =  185.910 DEGREES KELVIN
NEW DENSITY     = .304E-05 KG/M**3
```

Figure 2-10. Estimation Summary Report

ATMOSPHERIC PARAMETERS OUTPUT REPORT : PART II

ALT	GMTSEC	M.WT	SC.HT	MACH NO	PN	PCDEV	E-W WD	N-S WD	ALTU	LATU	LONGU	E-W U	N-S U
93.47	64337.00	28.4480	5.735	27.43	.79828E+02	1.82	-9999.00	-9999.00	.09	.00	.00	0.00	0.00
92.07	64347.00	28.6261	5.676	27.48	.10151E+03	1.18	-9999.00	-9999.00	.09	.00	.00	0.00	0.00
90.70	64357.00	28.7695	5.637	27.50	.13156E+03	.68	44.21	-5.55	.09	.00	.00	0.00	0.00
89.34	64367.00	28.9644	5.503	27.73	.16447E+03	-.95	20.19	3.25	.09	.00	.00	0.00	0.00
88.01	64377.00	28.9644	5.660	27.34	.22341E+03	3.09	1.20	11.81	.09	.00	.00	0.00	0.00
86.71	64387.00	28.9644	5.826	26.93	.29101E+03	6.96	-18.22	24.51	.09	.00	.00	0.00	0.00
85.45	64397.00	28.9644	5.500	27.71	.32917E+03	1.42	-26.69	29.31	.09	.00	.00	0.00	0.00
84.23	64407.00	28.9644	5.288	28.24	.39982E+03	-2.27	-29.14	31.43	.08	.00	.00	0.00	0.00
83.07	64417.00	28.9644	5.297	28.19	.46877E+03	-2.05	-29.19	29.39	.08	.00	.00	0.00	0.00
81.99	64427.00	28.9644	5.332	28.07	.56940E+03	-1.60	-28.14	24.39	.08	.00	.00	0.00	0.00
80.99	64437.00	28.9644	5.382	27.90	.67577E+03	-1.03	-27.35	16.98	.08	.00	.00	0.00	0.00
80.08	64447.00	28.9644	5.438	27.72	.76711E+03	-.45	-26.59	8.86	.08	.00	.00	0.00	0.00
79.28	64457.00	28.9644	5.505	27.50	.90438E+03	.14	-25.41	1.04	.08	.00	.00	0.00	0.00
78.61	64467.00	28.9644	5.568	27.30	.98323E+03	.65	-24.08	-5.59	.08	.00	.00	0.00	0.00
78.06	64477.00	28.9644	5.622	27.11	.11004E+04	1.06	-22.82	-10.96	.08	.00	.00	0.00	0.00
77.63	64487.00	28.9644	5.667	26.94	.11187E+04	1.36	-21.46	-14.94	.08	.00	.00	0.00	0.00
77.28	64497.00	28.9644	5.704	26.79	.11803E+04	1.59	-20.13	-17.98	.08	.00	.00	0.00	0.00
77.00	64507.00	28.9644	5.735	26.65	.12796E+04	1.76	-19.03	-20.37	.07	.00	.00	0.00	0.00
76.77	64517.00	28.9644	5.761	26.52	.12894E+04	1.89	-18.06	-22.32	.07	.00	.00	0.00	0.00
76.55	64527.00	28.9644	5.787	26.39	.13326E+04	2.01	-17.08	-24.13	.07	.00	.00	0.00	0.00
76.34	64537.00	28.9644	5.812	26.26	.13677E+04	2.12	-16.18	-26.01	.07	.00	.00	0.00	0.00
76.14	64547.00	28.9644	5.836	26.13	.14016E+04	2.22	-15.19	-27.49	.07	.00	.00	0.00	0.00
75.94	64557.00	28.9644	5.859	26.00	.14157E+04	2.31	-14.18	-28.82	.07	.00	.00	0.00	0.00
75.76	64567.00	28.9644	5.881	25.88	.14409E+04	2.39	-13.18	-29.99	.07	.00	.00	0.00	0.00
75.59	64577.00	28.9644	5.902	25.76	.14690E+04	2.45	-12.22	-30.99	.07	.00	.00	0.00	0.00
75.45	64587.00	28.9644	5.921	25.64	.14890E+04	2.50	-11.31	-31.84	.07	.00	.00	0.00	0.00
75.31	64597.00	28.9644	5.938	25.53	.15029E+04	2.54	-10.48	-32.54	.07	.00	.00	0.00	0.00
75.18	64607.00	28.9644	5.955	25.41	.15343E+04	2.58	-9.64	-33.19	.07	.00	.00	0.00	0.00
75.05	64617.00	28.9644	5.972	25.30	.15577E+04	2.61	-8.78	-33.79	.07	.00	.00	0.00	0.00
74.91	64627.00	28.9644	5.993	25.18	.15804E+04	2.71	-7.88	-34.34	.06	.00	.00	0.00	0.00
74.78	64637.00	28.9644	6.015	25.05	.16074E+04	2.84	-6.96	-34.85	.06	.00	.00	0.00	0.00
74.64	64647.00	28.9644	6.037	24.92	.16139E+04	2.98	-6.00	-35.31	.06	.00	.00	0.00	0.00
74.49	64657.00	28.9644	6.059	24.79	.16313E+04	3.11	-4.89	-35.85	.06	.00	.00	0.00	0.00
74.35	64667.00	28.9644	6.082	24.66	.16579E+04	3.25	-3.83	-36.21	.06	.00	.00	0.00	0.00
74.20	64677.00	28.9644	6.106	24.53	.16823E+04	3.39	-2.75	-36.50	.06	.00	.00	0.00	0.00
74.05	64687.00	28.9644	6.129	24.40	.16951E+04	3.53	-1.65	-36.71	.06	.00	.00	0.00	0.00
73.90	64697.00	28.9644	6.152	24.26	.17083E+04	3.66	-.53	-36.83	.06	.00	.00	0.00	0.00
73.75	64707.00	28.9644	6.175	24.13	.17339E+04	3.78	.56	-36.88	.06	.00	.00	0.00	0.00
73.62	64717.00	28.9644	6.196	24.00	.17571E+04	3.89	1.59	-36.84	.06	.00	.00	0.00	0.00
73.48	64727.00	28.9644	6.216	23.86	.17737E+04	3.99	2.73	-36.72	.06	.00	.00	0.00	0.00

Figure 2-12. Atmospheric Parameters Output Report (Part 2)

2.2.5 ERROR SUMMARY REPORT

The Error Summary Report is the last report generated. If any errors occurred during the execution of LAIRS, a message identifying these errors is printed in the Error Summary Report.

SECTION 3 - SYSTEM DESCRIPTION

This section describes the requirements for LAIRS and the software developed to fulfill these requirements.

3.1 SOFTWARE REQUIREMENTS

The LAIRS software must perform the following functions (Reference 1):

- Respond to user input specifying program options
- Receive as input an ENTREE Program trajectory file containing Shuttle position vectors as a function of time
- Receive as input meteorological observation files containing vertical profiles of temperature, pressure, density, and winds taken at up to three locations along or near the Shuttle reentry path
- Produce values of the temperature, pressure, density, and winds for selected points along the Shuttle trajectory using the input meteorological data or default data
- Produce output reports and an output user file containing the values of the calculated parameters

3.2 DESCRIPTION OF LAIRS MODELING CAPABILITIES

LAIRS is designed for flexibility. A variety of parameter calculation modes are available, and the user may choose the one or ones best suited to his needs. All LAIRS model types are designed to operate in two basic modes: default and adjusted. In the default mode, the source of data used by the model is the Edwards Reference Atmosphere (0-25 kilometers)(Reference 2), updated to remove discrepancies, and the Cospar International Reference Atmosphere (CIRA) 1972 profiles (25-110 kilometers)(Reference 3). This data is stored on a permanent file (see Appendix B), which also contains latitude gradients and diurnal and semidiurnal variation coefficients for temperature, pressure, and density. These values were obtained from Reference 3 except for the latitude gradients below 25 kilometers, which were obtained from the Handbook of Geophysics (1965) (Reference 4). In the adjusted mode, the meteorological observations described in Appendix B are used as input to the model.

The models used in LAIRS are:

- Interpolation of atmospheric parameters at points on the Shuttle trajectory. This is the most straightforward model available in LAIRS.

  When more than one meteorological profile is available, the user may choose between two interpolation schemes. The first consists of univariate interpolation in altitude* on each profile, followed by univariate interpolation in distance between profiles. The second, and more sophisticated, scheme involves univariate interpolation in altitude, followed by bivariate interpolation in latitude and local solar time. This method requires the use of latitude gradients.

  When only one profile is available, as in the default case or when only one meteorological observations file is available, the interpolation model consists merely of a univariate interpolation in altitude followed by (at the user's request) translation of the interpolated values in latitude and local solar time to the Shuttle location. This translation makes use of the diurnal and semidiurnal

*All altitude interpolation is Lagrangian for the temperature and exponential for the pressure and density.

coefficients and the latitude gradients stored on the permanent file.

- The Jacchia-Roberts model (for use only above 90 kilometers). This model returns values of temperature, pressure, and density for any input point above 90 kilometers (wind components are not produced by the Jacchia-Roberts model). The only data that must be input to the model are the geomagnetic index (K_p) and solar flux $F_{10.7}$ values (stored on a permanent file), together with boundary values of temperature and density at 90 kilometers. These boundary values are chosen to match the model being used below 90 kilometers and are thus taken from either the default CIRA profiles or the meteorological profiles.

  Diurnal and latitude effects are incorporated in the Jacchia-Roberts model. The coefficients and gradients stored on the permanent file are not required. No uncertainties are estimated by the model.

- The fitted polynomial model (for use only below 90 kilometers). In this scheme, the atmosphere is broken into three segments (0-25 kilometers, 25-65 kilometers, and 65-90 kilometers), and the data in each segment are fitted separately to polynomials. Winds are not treated in this model, but may be interpolated from the meteorological data. The polynomial coefficients produced by the model correspond to a single vertical profile at a reference latitude and reference local solar time. At each altitude on the Shuttle trajectory, the atmospheric parameters are calculated from the polynomial coefficients and translated to the Shuttle latitude and local solar time by means of the diurnal and semidiurnal coefficients and the latitude gradients. Uncertainty estimates are derived from the residual sum of squares of the polynomial fit.

When the default profile is used, or when only one meteorological file is available, the model reference latitude and local solar time are taken to be those of the profile. Then the profile is sent to the polynomial fitting routines for calculation of the polynomial coefficients. If more than one meteorological file is to be used, the data must first be translated to a single reference latitude and local solar time by utilizing diurnal/semidiurnal coefficients and latitude gradients. The single resulting reference profile is then sent to the polynomial fitting routines.

The polynomial fitting itself can take one of two forms at the user's request. The first is simply linear least squares fitting of the temperature and the logarithms of pressure and density. The second is the differential correction (DC) process discussed in Section 4. The linear least squares process requires as input a reference profile containing temperature, pressure, and density measurements, while the DC process can use as input a reference profile containing any one of these measurement types alone or any combination of them.

A related aspect of the polynomial model is the integration of temperature to yield pressure and density after the polynomial coefficients have been calculated. This is an option available when the linear least squares process is used, but occurs automatically when the DC process is used, as the DC process produces only temperature coefficients.

- Adjustment of diurnal/semidiurnal coefficients and latitude gradients. This is not actually a complete model, but is an option the user may wish to select in addition to one of the preceding models. It consists of the utilization of meteorological data to update the default coefficients and gradients on the permanent file. At least two meteorological profiles must exist for this option to be used. The user should note, however, that this process is highly dependent on the quantity and quality of the meteorological data and may not always yield good results.

3.3 LAIRS STRUCTURE AND FLOW

The diagrams in Figure 3-1 show the hierarchy and modular structure of the LAIRS Program. Routine LAIRS serves as the executive driver of the system. After READIN has processed the input keyword card deck, WFILE builds the working file from the permanent file and, if required, calls TRNADJ to update the latitude gradients and diurnal/semidiurnal coefficients. MODADJ controls the model adjustment process; after it is called, the polynomial coefficients exist in COMMON. PARAMS is responsible for calling the proper I/O routines to input a trajectory point and output the calculated parameters and for calling MODELS, an executive that selects the proper atmospheric modeling routines for each trajectory point.

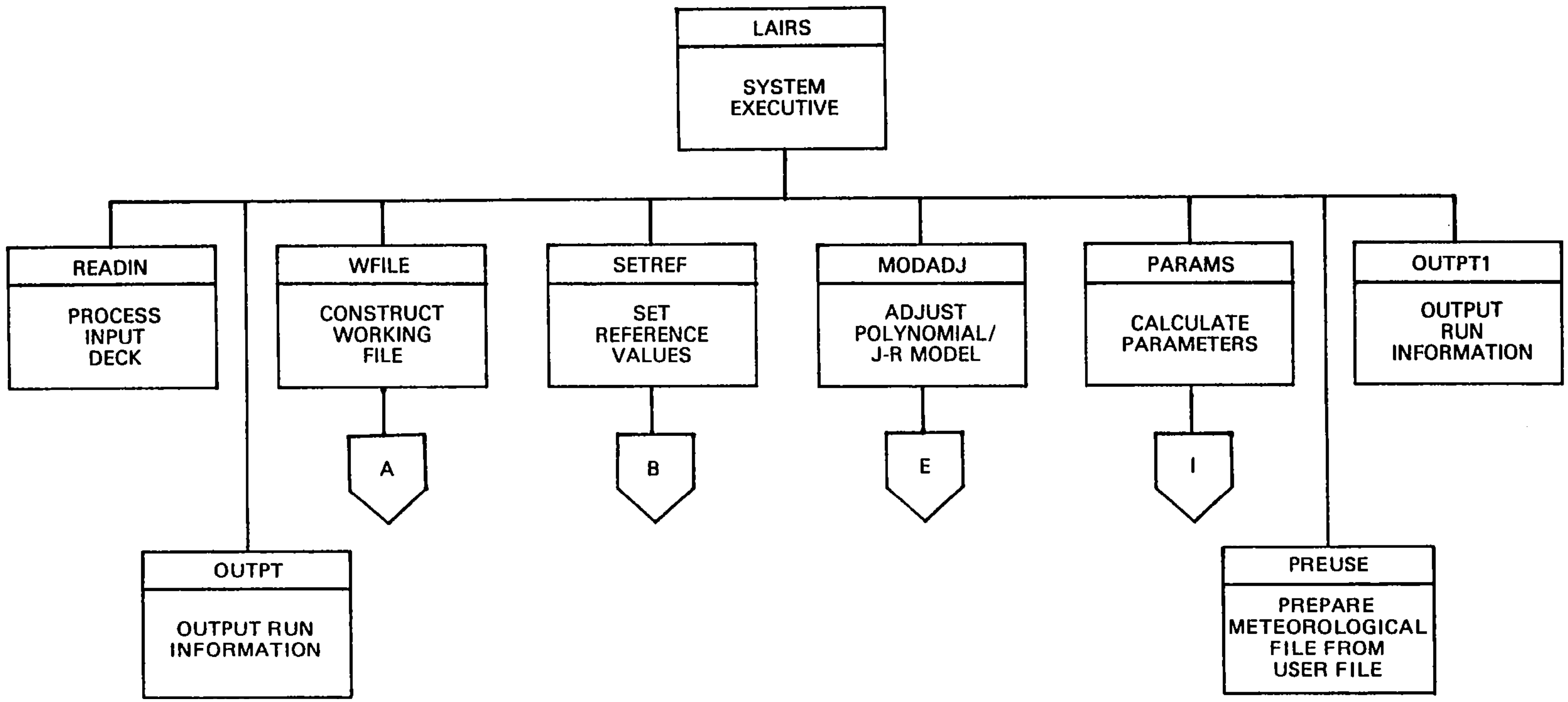


Figure 3-1. LAIRS Program Hierarchy (1 of 14)

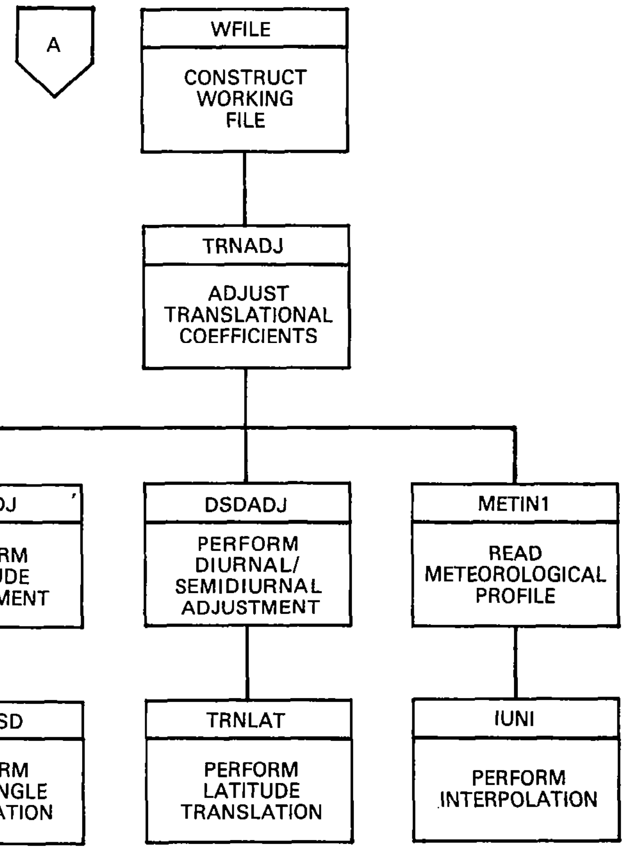


Figure 3-1. LAIRS Program Hierarchy (2 of 14)

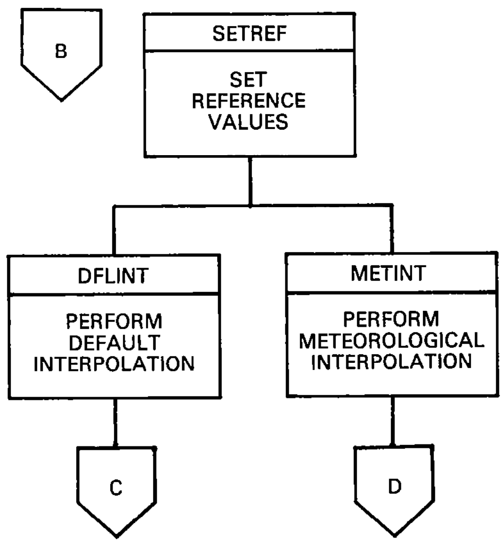


Figure 3-1. LAIRS Program Hierarchy (3 of 14)

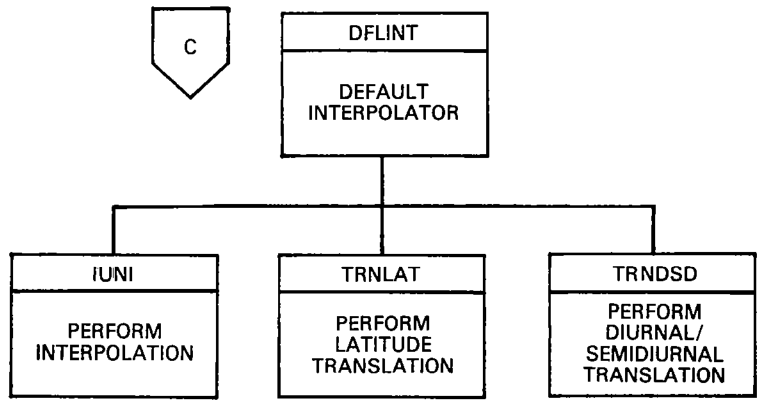


Figure 3-1. LAIRS Program Hierarchy (4 of 14)

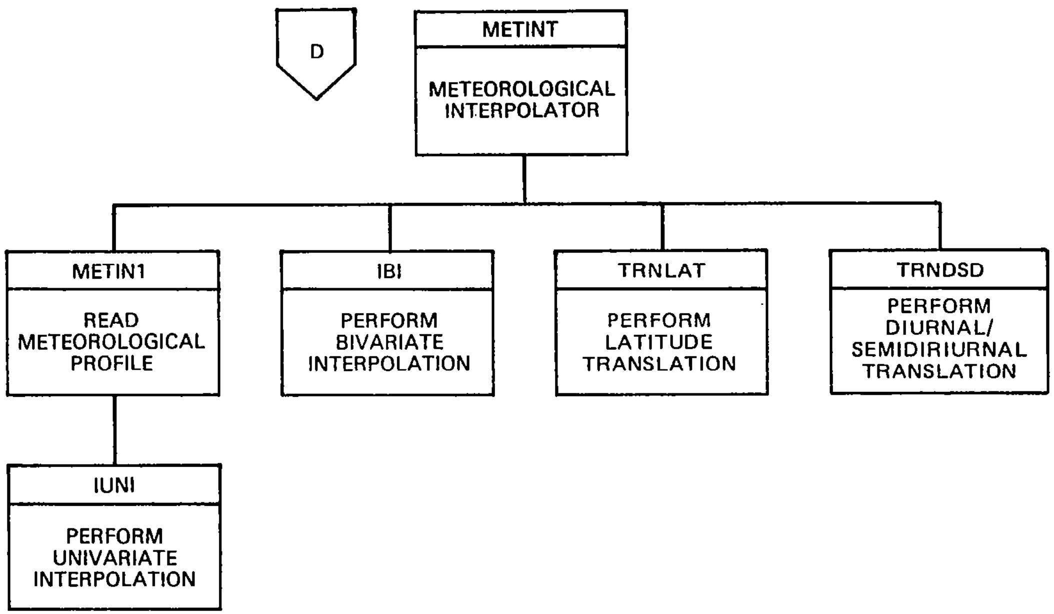
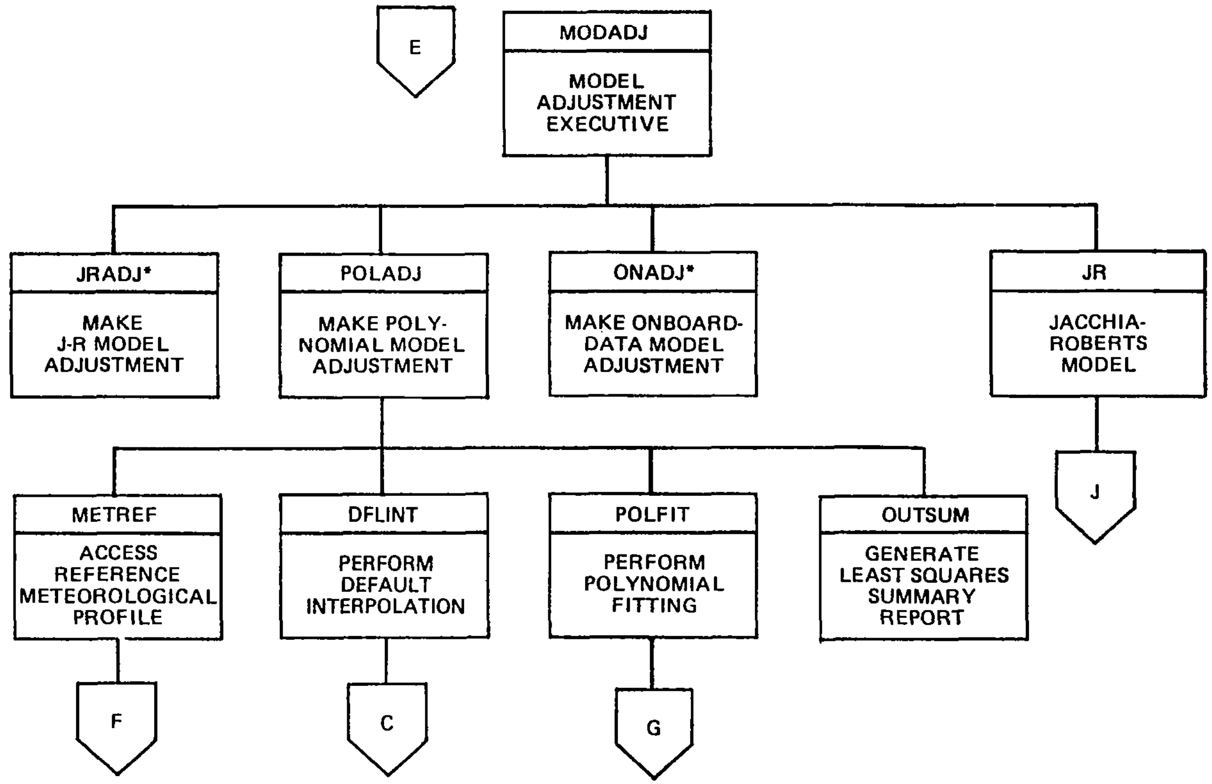


Figure 3-1. LAIRS Program Hierarchy (5 of 14)



*DUMMY STUB FOR FUTURE IMPLEMENTATION.

Figure 3-1. LAIRS Program Hierarchy (6 of 14)

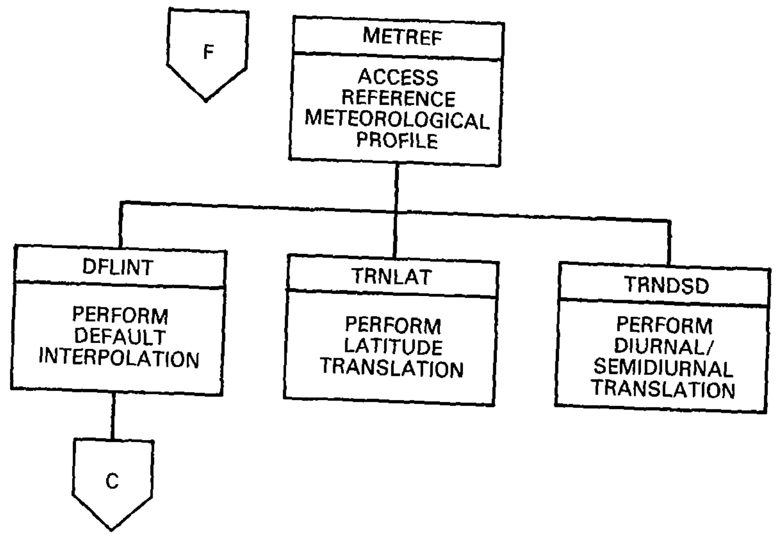


Figure 3-1. LAIRS Program Hierarchy (7 of 14)

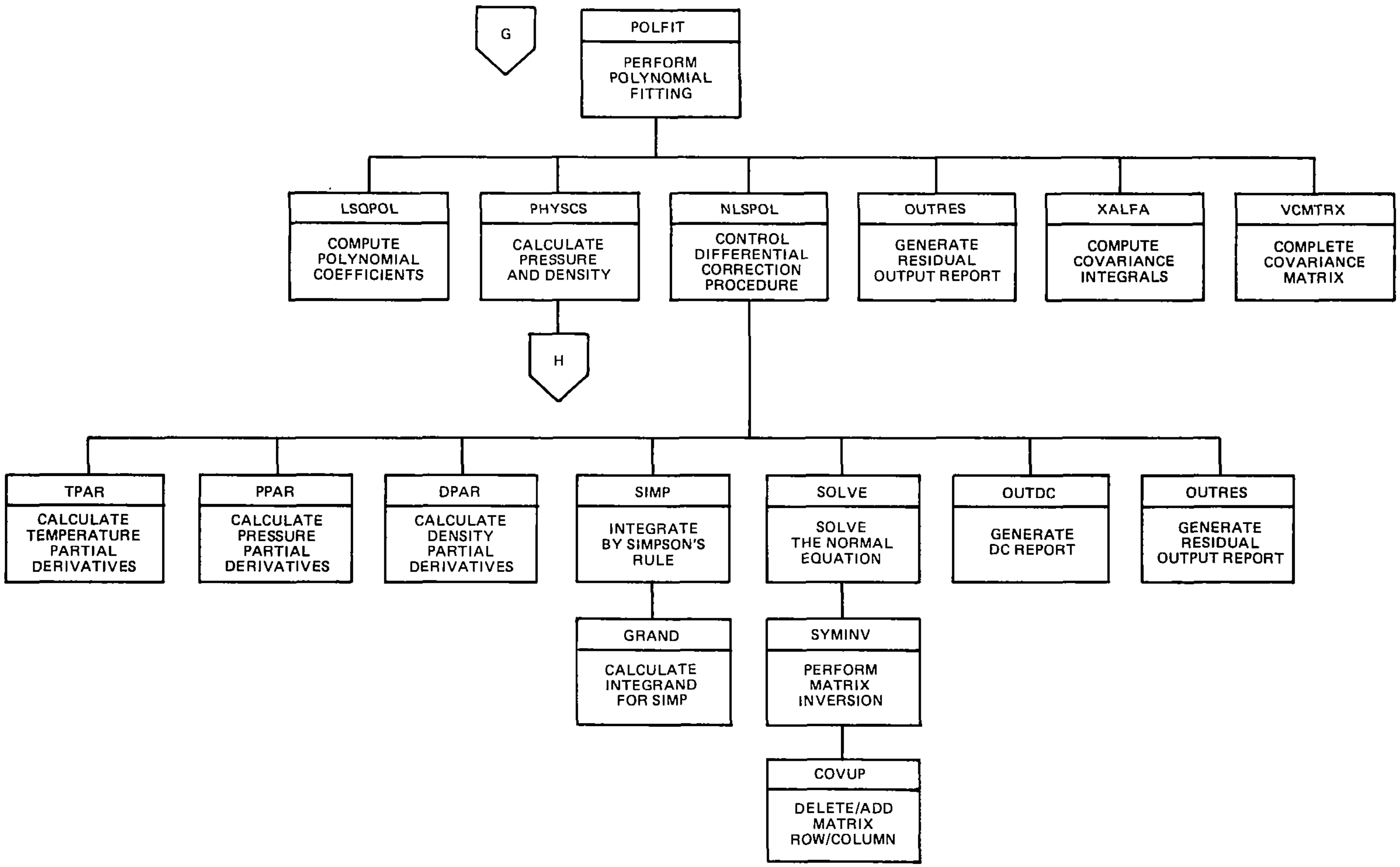


Figure 3-1. LAIRS Program Hierarchy (8 of 14)

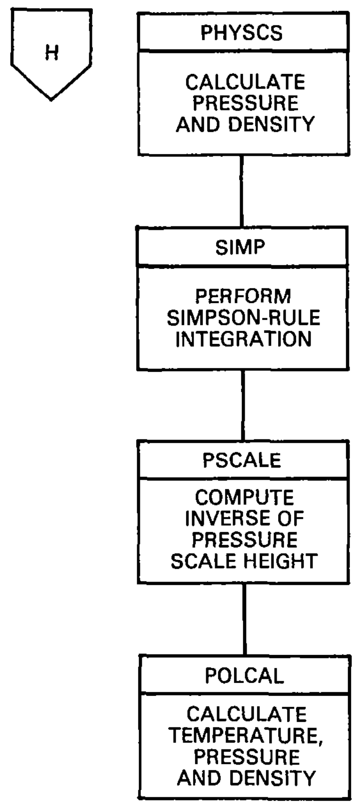
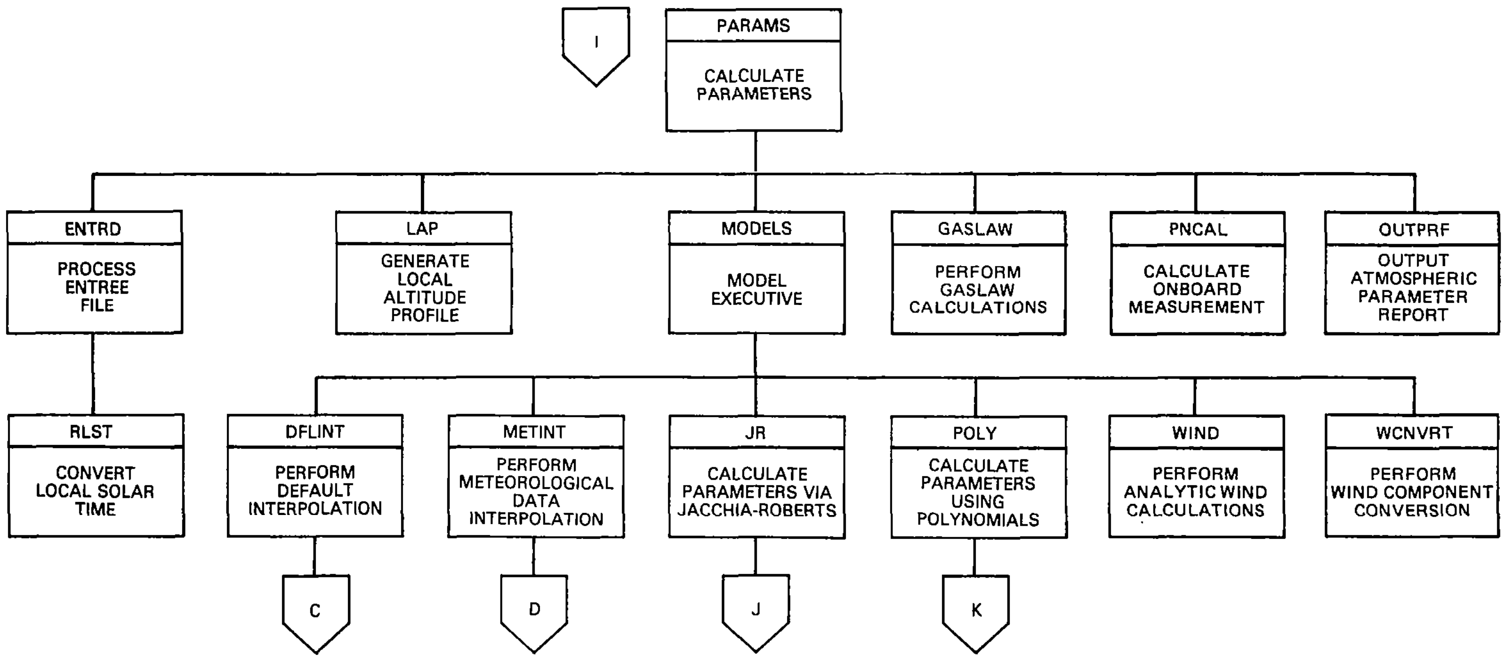


Figure 3-1. LAIRS Program Hierarchy (9 of 14)



*DUMMY STUB FOR POSSIBLE FUTURE IMPLEMENTATION.

Figure 3-1. LAIRS Program Hierarchy (10 of 14)

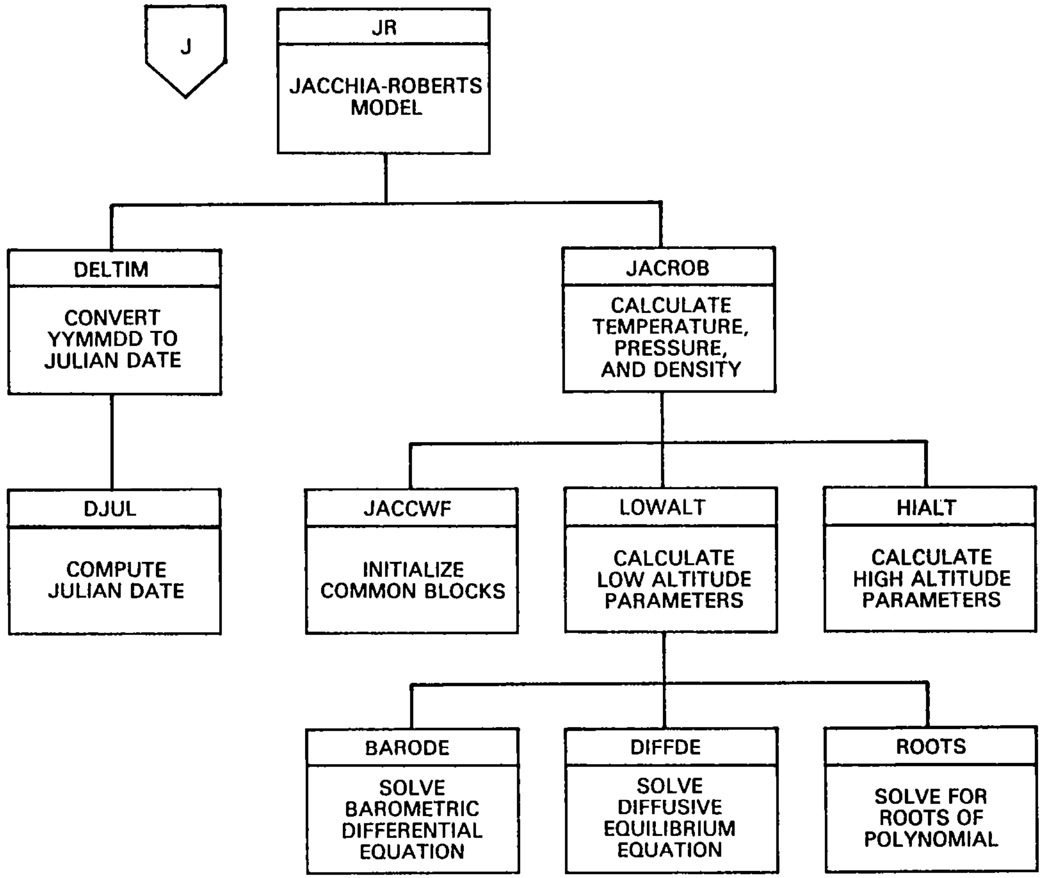


Figure 3-1. LAIRS Program Hierarchy (11 of 14)

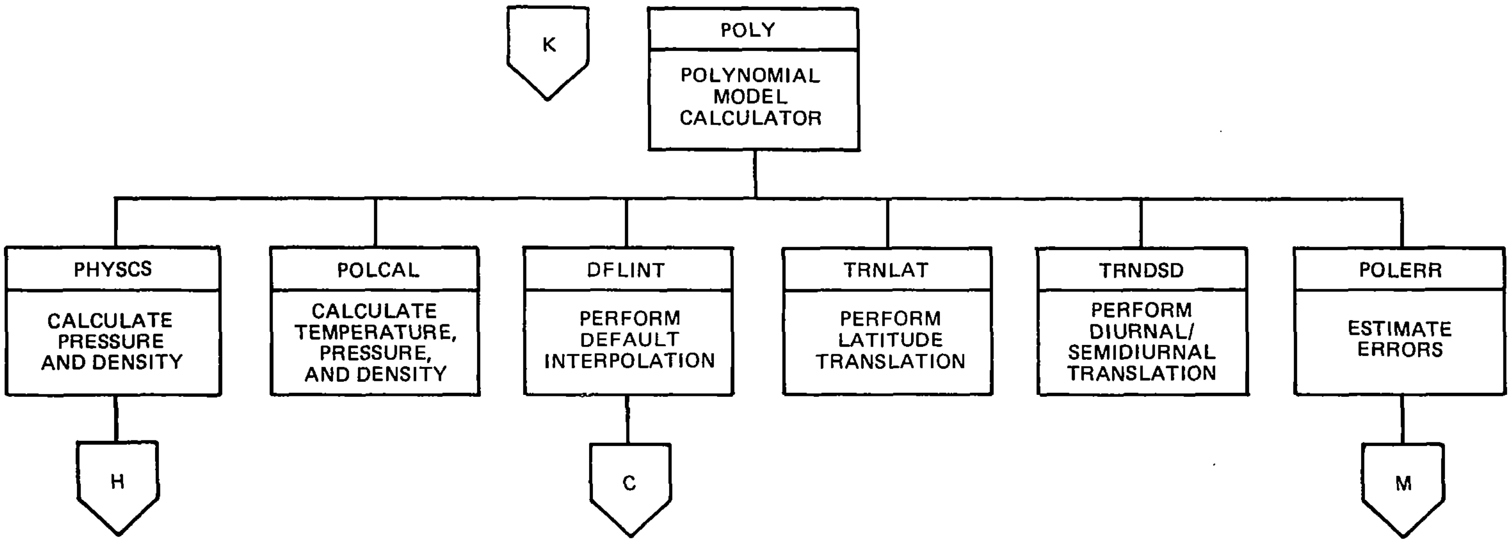
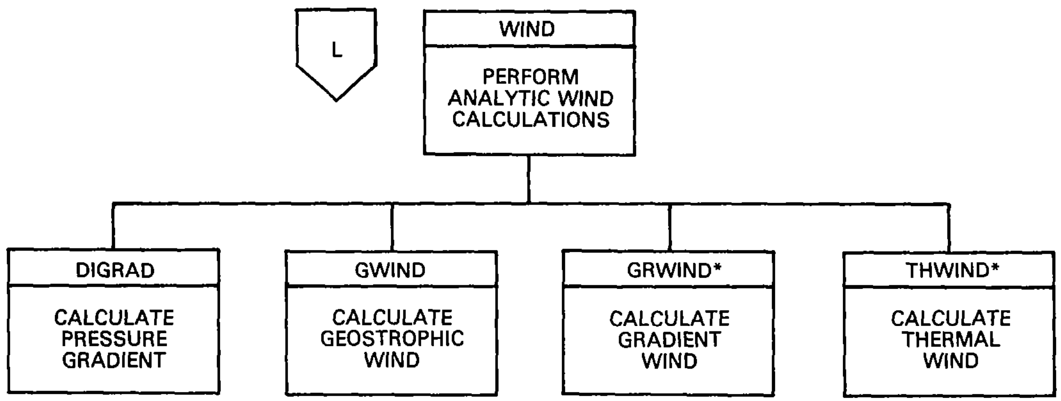
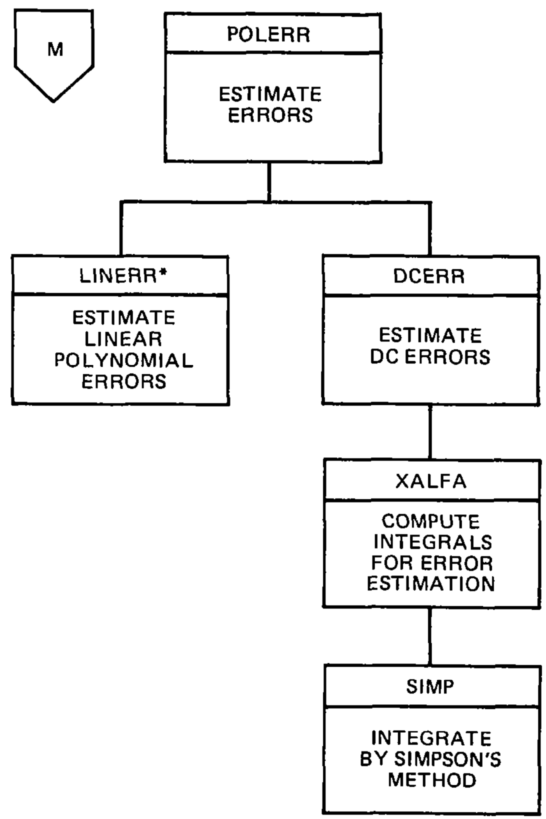


Figure 3-1. LAIRS Program Hierarchy (12 of 14)



*DUMMY STUB FOR POSSIBLE FUTURE IMPLEMENTATION.

Figure 3-1. LAIRS Program Hierarchy (13 of 14)



*DUMMY STUB FOR FUTURE IMPLEMENTATION.

Figure 3-1. LAIRS Program Hierarchy (14 of 14)

3.4 SUBROUTINE DESCRIPTIONS

Subroutine descriptions for all the subroutines that comprise the LAIRS Program are given in this section. These descriptions are also included in the prologue of each respective subroutine. The subroutine descriptions are presented in alphabetical order and are preceded by a list that gives the name and a brief description of the function of each subroutine.

LAIRS MODULE DESCRIPTIONS

BARODE	Solves the barometric equation for the region between 90 and 125 kilometers for the Jacchia-Roberts model
COVUP	Deletes or adds a row or column in the normal matrix
DCERR	Controls differential correction error estimation process
DELTIM	Turns packed date (YYMMDD.) into Julian date
DFLINT	Interpolates temperature, pressure, density, and winds from working (default) file
DIFFDE	Solves the diffusive equilibrium equation for the region between 20 and 125 kilometers for the Jacchia-Roberts model
DIGRAD	Produces longitudinal gradients from diurnal and semidiurnal coefficients
DJUL	Computes the Julian date (called by DELTIM)
DPAR	Calculates density partial derivatives for the differential correction process
DSDADJ	Adjusts the diurnal and semidiurnal coefficients
ENTRD	Reads a block of Shuttle trajectory points from the ENTREE file
GASLAW	Recalculates temperature from pressure and density via gas law and performs related gas law computations
GRAND	Calculates integrand for the differential correction process

GWIND	Calculates the geostrophic wind
HIALT	Calculates the temperature, pressure, and density in the region above 125 kilometers for the Jacchia-Roberts model
HMSCON	Converts hours, minutes, and seconds into decimal seconds
IBI	Performs bivariate interpolation (FORTRAN library routine)
IUNI	Interpolates using Lagrange's univariate method (FORTRAN library routine)
JACCWF	Retrieves values from K_p file for Jacchia-Roberts routines
JACROB	Controls Jacchia-Roberts temperature, pressure, and density calculations
JR	Controls flow of Jacchia-Roberts model
LAIRS	Controls flow of Langley Atmospheric Information Retrieval System (LAIRS)
LAP	Generates altitude points for a Local Atmospheric Profile (LAP)
LATADJ	Adjusts latitude gradient
LOWALT	Computes the temperature, pressure, and density in the region between 90 and 125 kilometers for the Jacchia-Roberts model
LSQPOL	Fits linear least-squares polynomial (FORTRAN library routine)
METINT	Interpolates temperature, pressure, density, and winds from meteorological observation files
METIN1	Interpolates raw meteorological profiles

METREF	Produces reference meteorological profile (unfitted)
MODADJ	Controls model adjustment process
MODELS	Retrieves temperature, pressure, density, and wind components for specified trajectory point via chosen model
NLSPOL	Controls fitting of nonlinear least squares polynomial
OUTDC	Outputs differential correction iteration report
OUTPRF	Outputs atmospheric parameter report and user file
OUTPT	Outputs LAIRS report header and summaries
OUTPT1	Outputs second half of atmospheric parameter report
OUTRES	Outputs residual report
OUTSUM	Outputs summary report of the differential correction coefficients
PARAMS	Controls flow of the atmospheric parameter calculations for Shuttle trajectory or LAP
PHYSCS	Calculates pressure and density from temperature via physical relationships
PNCAL	Calculates estimated onboard pressure measurement and Mach number
POLADJ	Controls polynomial model adjustment
POLCAL	Calculates temperature, pressure, and density from polynomial coefficients
POLERR	Controls error estimation for the polynomial model

POLFIT	Fits reference meteorological profile to polynomial model
POLY	Controls calculation of parameters via polynomial model
PPAR	Calculates pressure partial derivatives for differential correction process
PREUSE	Prepares a new meteorological file from a standard LAIRS output user file (USE)
PSCALE	Computes pressure scale height
READIN	Reads input keyword card deck
RLST	Calculates local solar time
ROOTS	Calculates desired complex roots of a given polynomial
SETREF	Sets reference values of parameters
SIMP	Performs integration by Simpson's rule (FORTRAN library routine)
SOLVE	Solves the normal equation and updates the solve-for parameters
SYMINV	Inverts a symmetric matrix
TPAR	Calculates temperature partial derivatives for differential correction process
TRNADJ	Controls adjustment of translational coefficients
TRNDSD	Translates atmospheric parameters in local solar time
TRNLAT	Translates atmospheric parameters in latitude
VCMTRX	Completes calculation of the 5x5 variance-covariance matrix for differential correction error estimation

WCNVRT	Converts wind components (U and V) to wind speed and direction, or vice versa
WFILE	Builds working file from permanent file
WIND	Controls the calculation of the analytic wind components
XALFA	Computes integrals for differential correction variance-covariance matrix

```
SUBROUTINE BARODE(RHO,T,P)

 PURPOSE
  SUBROUTINE BARODE IS CALLED BY LOWALT TO COMPUTE THE ATMOSPHERIC
  DENSITY BETWEEN 90 AND 100 KM.

METHOD: 1.  EVALUATE THE SERIES BI
        2.  COMPUTE S(R)
        3.  EVALUATE THE EXPONENT PI
        4.  COMPUTE THE MOLECULAR MASS AT THIS ALTITUDE
        5.  COMPUTE THE F-FACTORS
        6.  COMPUTE THE UNCORRECTED DENSITY
        7.  COMPUTE THE TEMPERATURE AND PRESSURE FROM BENSITY

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O    DESCRIPTION
   RHO        R      O    DENSITY
   T          R      O    TEMPERATURE
   P          R      O    PRESSURE

CALLING SUBROUTINE:  LOWALT

SUBROUTINES CALLED:  NONE

 COMMON BLOCK PARAMETERS
NAME      DIMEN     COMMON I/O DESCRIPTION
AC           7       JRCOM  I   MOLECULAR POWER SERIES COEFFICIENTS
AD           6       JRCOM  I   CONSTANT COEFFICIENTS FOR B(N) SERIES
BD           6       JRCOM  I   LINEAR COEFFICIENTS FOR B(N) SERIES
FKL          1       JRCOM  I   FACTOR INVOLVED IN RHO COMPUTATION
FLC4         1       JRCOM  I   MODIFYING FACTOR
GLO          1       JRCOM  I   MEAN SURFACE GRAVITY
HGT          1       JRCOM  I   HEIGHT OF SPACECRAFT
RC           1       JRCOM  I   UNIVERSAL GAS CONSTANT
RCM          1       JRCOM  I   AVERAGE EARTH RADIUS
RHOZ         1       JRCOM  I   ATMOSPHERIC DENSITY AT 90KM
RL1          1       JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND
RL2          1       JRCOM  I   ROOT OF POLFNOMIAL IN INTEGRAND
TX           1       JRCOM  I   INFLECTION POINT TEMPERATURE
TZ           1       JRCOM  I   TEMPERATURE AT HEIGHT Z
TO           1       JRCOM  I   TEMPERATURE AT MINIMUM HEIGHT
UC           2       JRCOM  I   FUNCTIONAL VALUES AT RL1 AND RL2
VCDI         1       JRCOM  I   FACTOR INCLUDEDIN RHO COMPUTATION
WC           2       JRCOM  I   FUNCTIONAL VALUES AT RL1 AND RL2
XCDI         1       JRCOM  I   FACTOR INCLUDEDIN RHO COMPUTATION
XLPS         1       JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND
YLPS         1       JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND
ZJO          1       JRCOM  I   MINIMUM HEIGHT

 PROGRAMMER
  J. P. MOLINEAUX, COMPUTER SCIENCES CORPORATION
```

Subroutine BARODE

```
      SUBROUTINE COVUP(MODE,NN,MN,IJ,ND,S,IERR)

PURPOSE:
      COVUP DELETES THE ROWS AND COLUMNS OF NORMAL MATRIX
      WHICH ARE ZEROS OR ADD THE ZEROED ROWS AND COLUMNS
      TO THE INVERSE
ARGUMENT LIST:
 ARGUMENT  TYPE  I/O   DESCRIPTION
  MODE       I    I    =1 DELETE ROW/COLUMN
                       =2 ADD IJ ZERO ROW/COLUMNS SPECIFIED BY MN
  NN         I    I    S1 INDEX OF ROW/COLUMN INDEX TO BE REMOVED
  MN         I    I    ROW NUMBERS THAT HAVE BEEN DELETED FROM
                       NORMAL MATRIX. MAXIMUM IS 20.
  IJ         I    O    TOTAL NUMBER OF ROW/COLUMNS DELETED
  ND         I    I    ORIGINAL DIMENSION OF NORMAL MATRIX
  S          R    I    NORMAL MATRIX IN UPPER TRIANGULAR FORM

CALLING SUBROUTINE: SYMINV

SUBROUTINES CALLED: NONE

PROGRAMMER: ANN WELKER, CSC
            MODIFIED FOR LAIRS BY D. E. BOLAND  MARCH 1981
```

Subroutine COVUP

```
    SUBROUTINE DCERR(ISEGM,ZBOUND,DZ,T,P,D,UT,UP,UD,IERR)

PURPOSE:
    DCERR COMPUTES 1-SIGMA UNCERTAINTY FOR ATMOSPHERIC
    PARAMETERS CALCULATED THROUGH THE DC PROCESS

METHOD:
    1. COMPUTE PARTIAL DERIVATIVES OF TEMPERATURE, PRESSURE,
       AND DENSITY WITH RESPECT TO THE SOLVE-PARAMETERS
    2. COMBINE THE PARTIAL DERIVATIVES WITH THE VARIANCE-
       COVARIANCE MATRIX TO FIND UNCERTAINTIES

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
   ISEGM       I       I      SEGMENT NUMBER MINUS ONE
   ZBOUND      R       I      SEGMENT UPPER BOUNDARY ALTITUDE
   DZ          R       I      ALTITUDE WITH RESPECT TO THE UPPER
                              BOUNDARY
   T           R       I      TEMPERATURE
   P           R       I      PRESSURE
   D           R       I      DENSITY
   UT          R       O      COMPUTED TEMPERATURE UNCERTAINTY
   UP          R       O      COMPUTED PRESSURE UNCERTAINTY
   UD          R       O      COMPUTED DENSITY UNCERTAINTY
   IERR        I       O      ERROR FLAG

CALLING SUBROUTINES: POLERR

SUBROUTINES CALLED: XALFA

COMMON BLOCK PARAMETERS USED:
  COMMON NAME  PARAMETERS   I/O    DESCRIPTION
   /COFCOM/       CT         I      ARRAY OF TEMPERATURE COEFFICIENTS
                  CP         I      ARRAY OF PRESSURE COEFFICIENTS
                  COVAT      I      VARIANCE-COVARIANCE MATRIX
   /SOLAND/       KINT       O      NUMBER OF INTEGRALS TO BE COMPUTED
                                    BY XALFA
                  ZREF       O      REFERENCE ALTITUDE (SAME AS ZBOUND)
                  A          O      SOLVE-FOR PARAMETER ARRAY

EXTERNAL DATA SETS USED: NONE

PROGRAMMER:  T. LEE, CSC       SEPTEMBER 1981
```

Subroutine DCERR

```
SUBROUTINE DELTIM(MODE,YMD,HMS,TOJUL,REFJUL,DT)
PURPOSE
    TO COMPUTE THE TIME IN SECONDS RELATIVE TO A REFERENCE DATE,
    OR THE JULIAN DATE GIVEN A PACKED CALENDAR DATE
CALLING SEQUENCE
    CALL DELTIM(MODE,YMD,HMS,TOJUL,REFJUL,DT)
CALLING SEQUENCE VARIABLES
INPUT
MODE   = 1=COMPUTE JULIAN DATE AND RETURN IN TOJUL
         2=COMPUTE ELAPSED TIME REFERENCED TO REJUL, FROM YMD, HMS
YMD    = PACKED YEAR MONTH DAY
HMS    = PACKED HOUR MINUTE SECOND
REFJUL = REFERENCE JULIAN DATE
OUTPUT
TOJUL  = JULIAN DATE OF YMD, HMS
DT     = ELEPSED EPHEMERIS SECONDS PAST REFJUL
REFERENCES
    GTDS TASK NAME - TIME RELATIVE TO REFERENCE DATE (DELTIM)
PROGRAMMER
    ALLEN L. COHEN - COMPUTER SCIENCES CORP.
```

Subroutine DELTIM

```
     SUBROUTINE DFLINT(N,POS,TPDW,COEF,IERR)

PURPOSE:
   DFLINT CONTROLS THE DEFAULT INTERPOLATION FOR TEMPERATURE,
   PRESSURE,DENSITY,E-W AND N-S WIND COMPONENTS.  IT ALSO
   CONVERTS E-W AND N-S WINDS INTO WIND SPEED AND DIRECTION.

METHOD:
   1. READS IN DATA POINTS FROM WORKING FILE AND STORES VALUES IN
   ARRAYS.
   2. PASSES ARRAYS TO SUBROUTINE IUNI FOR INTERPOLATIONS.
   3. USES LOGARITHMIC INTERPOLATION FOR PRESSURE AND DENSITY.
   4. TRANSLATES TEMPERATURE, PRESSURE, AND DENSITY FOR LATITUDINAL,
   DIURNAL, AND SEMIDIURNAL VARIATIONS IF DESIRED.
   5. CONVERTS E-W AND N-S WIND COMPONENTS INTO WIND SPEED AND
   DIRECTION.

ARGUMENT LIST:
   ARGUMENT    TYPE    I/O    DESCRIPTION
      N          I      I      ATMOSPHERIC SEGMENT
                                  =0 , NO INTERPOLATION NEEDED
                                         (FLAG FOR MET. DATA)
                                  =1 , UPPER
                                  =2 , LOWER
      POS        R      I     3-WORD ARRAY:
                                  POS(1) = ALTITUDE (KM)
                                  POS(2) = LATITUDE (DEGREES)
                                  POS(3) = LOCAL SOLAR TIME (HOURS)
                                  POS(4) = LONGITUDE
      TPDW       R      O     7-WORD ARRAY:
                                  TPDW(1) = TEMPERATURE (DEG. K)
                                  TPDW(2) = PRESSURE    (N/M2)
                                  TPDW(3) = DENSITY     (KG/M3)
                                  TPDW(4) = E-W WIND(U) (M/SEC)
                                  TPDW(5) = N-S WIND(V) (M/SEC)
                                  TPDW(6) = WIND SPEED(WS) (M/SEC)
                                  TPDW(7) = WIND DIR.(WD) (DEG.FROM N)
      COEF       R      O     15-WORD ARRAY:
                                  LATITUDE GRADIENTS OF TEMPERATURE,
                                  PRESSURE, AND DENSITY; DIURNAL
                                  AMPLITUDE, PHASE, SEMIDIURNAL AMPLI-
                                  TUDE, PHASE, FOR T, P, D
      IERR       I      O     ERROR FLAG
                                  =0 , NO ERROR

CALLING SUBROUTINES: PARAMS

SUBROUTINES CALLED:  WCNVRT,IUNI
```

Subroutine DFLINT (1 of 2)

FUNCTIONS CALLED: TRNLAT,TRNDSD

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	ILATL	I	INCLUDE LAT. VARIATIONS IN L.A. 0=NO 1=YES
	IDSDL	I	INCLUDE D/SD VARIATIONS IN L.A. 0=NO 1=YES
	ILATU	I	INCLUDE LAT. VARIATIONS IN U.A. 0=NO 1=YES
	IDSDU	I	INCLUDE D/SD VARIATIONS IN U.A. 0=NO 1=YES
	INTP	I	INTERPOLATER TYPE 1=1ST ORDER LAGRANGE 2=2ND ORDER LAGRANGE
	IDBG	I	DEBUG FLAG
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
	NWRK	I	INPUT LUN
/INTCOM/	IPT	I/O	POINTER USED IN IUNI INITIALLY SET TO -1
	IPTFLG	I	FLAG FOR FIRST CALL TO DFLINT
	ALT	I	ARRAY FOR ALTITUDES PASSED TO IUNI
	TPDWAR	I	ARRAY FOR T,P,D, AND WIND COMP. PASSED TO IUNI
	ARR	I	ARRAY FOR COEFF. PASSED TO TRANSLATING FUNCTIONS

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
WRK	NWRK	READ
OUT	NPRINT	WRITE

PROGRAMMER: R.A. KUSESKI, CSC

Subroutine DFLINT (2 of 2)

SUBROUTINE DIFFDE(RHO,T,P)

PURPOSE
DIFFDE IS CALLED BY LOWALT TO COMPUTE THE ATMOSPHERIC DENSITY VALUES FROM 100 KM TO 125 KM.

METHOD:
1. COMPUTE THE EXPONENTS QI
2. COMPUTE THE F FACTORS
3. COMPUTE THE CONSTITUENT DENSITIES
4. COMPUTE THE TOTAL DENSIITY
5. COMPUTE TEMPERATURE AND PRESSURE FROM DENSITY

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
RHO	R	O	DENSITY
T	R	O	TEMPERATURE
P	R	O	PRESSURE

CALLING SUBROUTINE: LOWALT

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS

NAME	DIMEN	COMMON	I/O	DESCRIPTION
ADT	6	JRCOM	I	THERMAL DIFFUSION COEFFICIENTS
CM	6	JRCOM	I	MASSES OF ATMOSPHERIC CONSTITUENTS IN GM/MOLE
FD125	5	JRCOM	O	INDIVIDUAL NUMBER DENSITIES
FKL	1	JRCOM	I	FACTOR INVOLVED IN RHO COMPUTATION
FLC4	1	JRCOM	I	MODIFYING FACTOR
GLO	1	JRCOM	I	MEAN SURFACE GRAVITY
HGT	1	JRCOM	I	HEIGHT OF SPACECRAFT
RC	1	JRCOM	I	UNIVERSAL GAS CONSTANT
RCM	1	JRCOM	I	AVERAGE EARTH RADIUS
RL1	1	JRCOM	I	ROOT OF POLYNOMIAL IN INTEGRAND
RL2	1	JRCOM	I	ROOT OF POLFNOMIAL IN INTEGRAND
SD	5	JRCOM	I	COEFFICIENTS FOR NUMBER DENSITY AT 100KM
TCIL	1	JRCOM	I	TEMPERATURE AT 100 KM.
TINF	1	JRCOM	I	EXOSPHERIC TEMPERATURE
TZ	1	JRCOM	I	TEMPERATURE AT HEIGHT Z
UC	2	JRCOM	I	FUNCTIONAL VALUES AT RL1 AND RL2
VCDI	1	JRCOM	I	FACTOR INCLUDEDIN RHO COMPUTATION
WC	2	JRCOM	I	FUNCTIONAL VALUES AT RL1 AND RL2
XCDI	1	JRCOM	I	FACTOR INCLUDEDIN RHO COMPUTATION
XLPS	1	JRCOM	I	ROOT OF POLYNOMIAL IN INTEGRAND
YLPS	1	JRCOM	I	ROOT OF POLYNOMIAL IN INTEGRAND
ZD	7	JRCOM	I	POWER SERIES COEFFICIENTS FOR RHO(100)/M

PROGRAMMER
J. P. MOLINEAUX, COMPUTER SCIENCES CORPORATION

Subroutine DIFFDE

```
      SUBROUTINE DIGRAD(DA,DPH,SDA,SDPH,ST,DLONG)

PURPOSE:
    DIGRAD PRODUCES THE LONGITUDINAL GRADIENT CORRESPONDING TO
    THE INPUT DIURNAL AND SEMIDIURNAL COEFFICIENTS (FOR ANY QUANTITY)

METHOD:
    1. EVALUATE THE TIME DERIVATIVE OF THE DIURNAL VARIATION.
    2. EVALUATE THE TIME DERIVATIVE OF THE SEMIDIURNAL VARIATION.
    3. CONVERT THE TOTAL DERIVATIVE TO UNITS OF DEGREES LONGITUDE.
    4. RETURN.

ARGUMENT LIST
  ARGUMENT   TYPE   I/O    DESCRIPTION
    DA         R     I      AMPLITUDE OF DIURNAL VARIATION
    DPH        R     I      PHASE OF DIURNAL VARIATION
    SDA        R     I      AMPLITUDE OF SEMIDIURNAL VARIATION
    SDPH       R     I      PHASE OF SEMIDIURNAL VARIATION
    ST         R     I      LOCAL SOLAR TIME AT WHICH DERIVATIVE
                             IS TO BE CALCULATED (HOURS)
    DLONG      R     O      LONGITUDINAL DERIVATIVE CORRESPONDING
                             TO INPUT D&SD COEFFICIENTS

CALLING SUBROUTINE: WIND

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /CONCOM/       TWOPI      I     TWO TIMES PI
                  HTD        I     HOURS TO DEGREES CONVERSION FACTOR

EXTERNAL DATA SETS USED: NONE
PROGRAMMER: D. E. BOLAND, CSC
```

Subroutine DIGRAD

REAL FUNCTION DJUL (Y,XM,D,HR,TM,SEC)

```
* * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * * *

      FORTRAN FUNCTION SUBPROGRAM

   PURPOSE
      TO COMPUTE THE MODIFIED JULIAN DATE OF A GIVEN GREGORIAN
      DATE AFTER 1950.0  (JULIAN DATE - 2430000 )

   USAGE
      REAL FUNCTION DJUL(Y,XM,D,HR,TM,SEC)

   INPUT
      Y - YEAR
      XM - MONTH
       D - DAY
      HR - HOURS
      TM - MINUTES
     SEC - SECONDS

   OUTPUT
       DJUL - THE MODIFIED JULIAN DATE

   REMARKS
      INPUT DATE MUST OCCUR AFTER 1950.0

   SUBROUTINES REQUIRED
       NONE
   PROGRAMMER
      M. MC GARRY
```

Real Function DJUL

SUBROUTINE DPAR(T,DTDS,RINT,DDDS)

PURPOSE:
DPAR COMPUTES PARTIAL DERIVATIVES OF DENSITY WITH RESPECT TO SOLVE-FOR PARAMETERS

METHOD:
COMPUTE THE PARTIAL DERIVATIVES OF DENSITY WITH RESPECT TO SOLVE-FOR PARAMETERS USING TEMPERATURE, TEMPERATURE PARTIAL DERIVATIVES AND INTEGRALS COMPUTED BY SIMP

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
T	R	I	COMPUTED TEMPERATURE
DTDS	R	I	COMPUTED TEMPERATURE PARTIAL DERIVATIVES
RINT	R	I	COMPUTED INTEGRALS
DDDS	R	O	LOG DENSITY PARTIAL DERIVATIVES COMPUTED

CALLING SUBROUTINE: NLSPOL

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/SOLAND/	IMAX	I	MAX. NUMBER OF INTEGRALS
	KSOLA4	I	=0 DOES NOT SOLVE FOR BOUNDARY TEMP. =1 SOLVES FOR BOUNDARY TEMP.
	NPOL	I	ORDER OF TEMP. POLYNOMIAL
	A	I	SOLVE-FOR PARAMETER ARRAY

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC   MARCH 1981

Subroutine DPAR

```
    SUBROUTINE DSDADJ(NF,F,A1,P1,A2,P2,DFLAT,TAU,RLAT)

PURPOSE:
    DSDADJ COMPUTES NEW DIURNAL AND SEMIDIURNAL COEFFICIENTS
    FOR ANY INPUT PARAMETER F (T, P, OR D) FROM METEOROLOGICAL
    DATA.

METHOD:
    1. TRANSLATE EACH INPUT PARAMETER F (UP TO THREE POINTS --
       ONE FROM EACH MET FILE) FROM ITS LATITUDE RLAT TO THE
       MODEL REFERENCE LATITUDE REFLAT TO REMOVE THE LATITUDE
       COMPONENT OF THE VARIATION OF F.
    2. LOAD THE 'C' ARRAY, CONSISTING OF THE COSINE TERMS
       TO BE USED IN SUBSEQUENT CALCULATIONS.
    3. IF ONLY THE DIURNAL COMPONENT OR ONLY THE SEMIDIURNAL
       COMPONENT HAS KNOWN DEFAULT VALUES, DO A LINEAR LEAST-
       SQUARES FIT FOR THE AMPLITUDE OF THE KNOWN COMPONENT.
    4. IF BOTH COMPONENTS HAVE KNOWN DEFAULT VALUES, THEN
       SOLVE FOR THE AMPLITUDES OF THE DIURNAL AND SEMIDIURNAL
       VARIATIONS (DEFAULT VALUES OF THE PHASES ARE USED).
       IF THERE ARE ONLY TWO POINTS (NF=2), CALCULATE THE
       AVERAGE VALUE OF F (FAV) USING THE DEFAULT VALUES OF
       THE COEFFICIENTS AND USE IT TO CALCULATE EXACTLY THE
       THE VALUES OF THE DIURNAL AND SEMIDIURNAL AMPLITUDES.
       IF NF=3, BOTH FAV AND THE AMPLITUDES MAY BE CALCULATED
       EXACTLY, THOUGH ONLY THE AMPLITUDES ARE CALCULATED.
    5. RETURN.

ARGUMENT LIST:
ARGUMENT    TYPE    I/O    DESCRIPTION
    NF        R      I       NUMBER OF POINTS OF F
    F         R      I       PARAMETER TO BE TRANSLATED
    A1        R     I/O      DIURNAL AMPLITUDE OF F
    P1        R     I/O      DIURNAL PHASE OF F
    A2        R     I/O      SEMIDIURNAL AMPLITUDE OF F
    P2        R     I/O      SEMIDIURNAL PHASE OF F
    TAU       R      I       LOCAL SOLAR TIME OF MET PROFILE
    DFLAT     R      O       LATITUDE GRADIENT OF F
    RLAT      R      I       LATITUDE OF MET PROFILE

CALLING SUBROUTINE: TRNADJ

SUBROUTINES CALLED: TRNLAT

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       REFLAT     I      MODEL REFERENCE LATITUDE
                  REFTAU     I      MODEL REFERENCE LOCAL SOLAR TIME

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC,     MARCH 1981
```

Subroutine DSDADJ

SUBROUTINE ENTRD(NZ,IEND,IERR)

PURPOSE:
ENTRD READS SHUTTLE TRAJECTORY POINTS FROM THE ENTREE FILE AND STORES THEM IN COMMON /CALCOM/.

METHOD:
1. READ A BLOCK OF TRAJECTORY POINTS FROM THE ENTREE FILE AND STORE THEM IN /CALCOM/.
2. CALL RLST TO CONVERT LONGITUDE AND GMT INTO LOCAL SOLAR TIME (ALSO STORED IN COMMON).
3. RETURN.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
IERR	I	O	ERROR FLAG: =0, NO ERROR
NZ	I	I	NUMBER OF POINTS IN BLOCK
IEND	I	O	END-OF-FILE FLAG (NO. PTS. IN LAST BLOCK)

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: RLST

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/CALCOM/	TRJ(5,10)	O	BLOCK OF 10 TRAJECTORY POINTS: ALTITUDE,LATITUDE,LONGITUDE,GMT, LOCAL SOLAR TIME
	UTRJ(5,10)		TRAJECTORY POINT UNCERTAINTIES
	V(10)		BLOCK OF SHUTTLE VELOCITIES
	ALPHA(10)		BLOCK OF SHUTTLE ANGLES-OF-ATTACK
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
	NENT	I	ENTREE FILE LUN
/USECOM/	IDBG	I	DEBUG FLAG
	NSAMP	I	SAMPLING INTERVAL

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE(DEBUG ONLY)
ENT	NENT	READ

PROGRAMMER: D. E. BOLAND, CSC, MARCH 1981

Subroutine ENTRD

```
    SUBROUTINE GASLAW(Z,TPDW,WTM,SCH,PCDEV)

PURPOSE:
    GASLAW CALCULATES CERTAIN PARAMETERS ASSOCIATED WITH THE IDEAL
    GAS LAW AND RECOMPUTES THE TEMPERATURE TO AGREE WITH THIS LAW.

METHOD:
    1. CONVERT MOLECULAR WEIGHT TO MKS AND CALCULATE THE RATIO
       OF PRESSURE TO DENSITY.
    2. COMPUTE THE PERCENT DEVIATION FROM THE GAS LAW BY
       COMPUTING THE GAS CONSTANT FROM THE INCOMING PARAMETERS
       AND COMPARING IT TO THE KNOWN VALUE.
    3. RECOMPUTE TEMPERATURE IN ACCORDANCE WITH THE GAS LAW.
    4. COMPUTE THE MOLECULAR WEIGHT.
    5. COMPUTE THE PRESSURE SCALE HEIGHT.
    6. RETURN.

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
    Z           R      I      SHUTTLE ALTITUDE (KM)
    TPDW(7)     R      I      CALCULATED ATMOSPHERIC PARAMETERS:
                               T,P,D,U,V,WS,WD (ONLY T,P,D USED)
    WTM         R      O      MOLECULAR WEIGHT
    SCHT        R      O      PRESSURE SCALE HEIGHT
    PCDEV       R      O      PERCENT DEVIATION FROM GAS LAW

CALLING SUBROUTINE: PARAMS

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O    DESCRIPTION
   /USECOM/       BOUND1     I      BOUNDARY BETWEEN UPPER AND LOWER
                                    ATMOSPHERIC MODELS (DEFAULT=90 KM)
                  IGAS       I      FLAG FOR DERIVATION OF T FROM GAS LAW
   /JRCOM/        RAV        I      AVERAGE EARTH RADIUS (KM)
                  RC         I      GAS CONSTANT (MKS UNITS)
                  GLO        I      SEA-LEVEL ACCELERATION OF
                                     GRAVITY (M/SEC**2)
                  CM         I      SEA-LEVEL MEAN MOLECULAR WEIGHT

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC       JULY, 1981
```

Subroutine GASLAW

SUBROUTINE GRAND(X,WK)

PURPOSE:
GRAND PREPARES THE INTEGRAND FOR SIMPSON INTEGRATOR

METHOD:
USING TEMPERATURE, MOLECULAR WEIGHT, GAS CONSTANT, AND GRAVITATIONAL ACCELERATION, COMPUTE THE INTEGRAND OF INTEGRALS NEEDED FOR PRESSURE AND DENSITY COMPUTATION AT A GIVEN ALTITUDE

ARGUMENT LIST:

ARGUMENT TYPE	I/O	DESCRIPTION
X	I	ALTITUDE
WK	O	COMPUTED INTEGRAND

CALLING SUBROUTINE: SIMP

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETERS	I/O	DESCRIPTION
/JRCOM/	RE	I	MEAN RADIUS OF THE EARTH
	RSTAR	I	GAS CONSTANT
	GS	I	SEA-LEVEL GRAV. ACCELERATION
	WM	I	MEAN MOLECULAR WEIGHT
/SOLAND/	NPOL	I	ORDER OF POLYNOMIAL
	IMAX	I	MAX. NUMBER OF INTEGRANDS
	ZREF	I	REFERENCE ALTITUDE: SEGMENT BOUNDARY
	A	I	SOLVE-FOR PARAMETERS

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC MARCH 1981

Subroutine GRAND

```
     SUBROUTINE GWIND(THETA,D,DPLAT,DPLONG,U,V)

PURPOSE:
    GWIND CALCULATES THE GEOSTROPHIC WIND FROM A GIVEN PRESSURE
    DISTRIBUTION.

METHOD:
    1. CONVERT THE LATITUDINAL AND LONGITUDINAL PRESSURE GRADIENTS
       FROM UNITS OF 1/DEGREES TO UNITS OF 1/METERS.
    2. CALCULATE THE WINDS FROM THE GEOSTROPHIC WIND EQUATON.
    3. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    THETA     R      I     LATITUDE
    DPLAT     R      I     LATITUDE PRESSURE GRADIENT
    DPLONG    R      I     LONGITUDE PRESSURE GRADIENT
    D         R      I     DENSITY
    U         R      O     EAST-WEST WIND COMPONENT (M/SEC)
    V         R      O     NORTH-SOUTH WIND COMPONENT (M/SEC)

CALLING SUBROUTINE: WIND

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
    /CONCOM/       R         I     EARTH EQUATORIAL RADIUS
                   ANG       I     EARTH ANGULAR VELOCITY
                   RTD       I     RADIANS TO DEGREES CONVERSION
                                   FACTOR

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC
```

Subroutine GWIND

```
SUBROUTINE HIALT(RHO,T,P)

  PURPOSE
    HIALT IS CALLED BY JACROB TO FURNISH DENSITY VALUES ABOVE 125 KM.

METHOD: 1.  EVALUATE CONSTANTS THAT RECUR FREQUENTLY
        2.  COMPUTE NUMBER DENSITIES OF N2,AR,HE,O2,O
        3.  COMPUTE THE SEASONAL LATITUDINAL DENSITY OF HELIUM AND
            MULTIPLY IT BY HELIUM'S CONTRIBUTION
        4.  CONVERT THE NUMBER DENSITIES TO MASS DENSITIES
        5.  COMPUTE HYDROGEN DENSITY
        6.  SUM THE SONSTITUENT DENSITIES TO GIVE THE TOTAL,
            UNCORRECTED DENSITY
        7.  COMPUTE TEMPERATURE AND PRESSURE FROM DENSITY

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
  RHO          R       O     ATMOSPHERIC DENSITY
  T            T       O     TEMPERATURE
  P            R       O     PRESSURE

CALLING SUBROUTINE:  JACROB

  CALLING SEQUENCE
    CALL HIALT (RHO)
    WHERE RHO IS THE OUTPUT ATMOSPHERIC DENSITY (PARTIAL, DUE TO
                 THE MODELLING OF EFFECTS ABOVE 125 KM.)

  COMMON BLOCK VARIABLES
 NAME      DIMEN     COMMON I/O DESCRIPTION
 ADT         6        JRCOM  I  THERMAL DIFFUSION COEFFICIENTS
 AVG         1        JRCOM  I  AVOGADRO'S NUMBER
 CF          1        JRCOM  I  CORRECTION FACTOR
 CFL         5        JRCOM  I  POWER SERIES COEFFICIENTS FOR CF
 CM          6        JRCOM  I  MASSES OF ATMOSPHERIC CONSTITUENTS
 D125        5        JRCOM  I  LOG INDIVIDUAL NO. DENSITIES AT 125 KM
 DELO        1        JRCOM  I  SUN'S LATITUDE
 GLO         1        JRCOM  I  MEAN SURFACE GRAVITY
 HGT         1        JRCOM  I  SPACECRAFT HEIGHT
 PHJ         1        JRCOM  I  S/C LATITUDE
 RC          1        JRCOM  I  UNIVERSAL GAS CONSTANT
 RCM         1        JRCOM  I  AVERAGE EARTH RADIUS
 TINF        1        JRCOM  I  EXOSPHERIC TEMPERATURE
 TWOPI       1       CONCOM  I  TWO TIMES PI
 TX          1        JRCOM  I  INFLECTION POINT TEMPERATURE
 TO          1        JRCOM  I  TEMPERATURE AT MINIMUM HEIGHT
 ZJX         1        JRCOM  I  INFLECTION POINT HEIGHT
 ZJO         1        JRCOM  I  MINIMUM HEIGHT

  PROGRAMMER
    A.K. KAPOOR,   COMPUTER SCIENCES CORPORATION
```

Subroutine HIALT

```
    FUNCTION HMSCON(HMS)

PURPOSE:
    HMSCON CONVERTS HOURS, MINUTES, SECONDS TO SECONDS.

METHOD:
    1. DECOMPOSE HOURS, MINUTES, SECONDS AND COMPUTE SECONDS.
    2. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    HMS       R      I     HOUR, MINUTES, SECONDS (HHMMSS.SSS)
    HMSCON    R      O     SECONDS CORRESPONDING TO HMS

CALLING SUBROUTINES: READIN

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC,      MARCH, 1981
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Function HMSCON

```
      SUBROUTINE JACCWF(T)

      VERSION 2.3
      PURPOSE
          JACCWF IS CALLED TO FILL COMMON BLOCK TKPTC WITH A TIME IT,
          MAGNETIC ACTIVITY INDICES AND EXOSPHERIC TEMPERATURES.

METHOD: 1.  CONVERT THE STARTING AND ENDING TIMES TO MODIFIED JULIAN
            JULIAN DATES, USING SUBROUTINE DELTIM
        2.  READ THE JACCHIA PERMANENT FILE HEADER  FILE KPILE
        3.  IF THE ARC WILL FIT IN COMMON/TKPTC/(END-START<20 DAYS),
            GO TO STEP 5
        4.  SINCE THE ARC IS MORE THAN 20 DAYS, SIMPLY DETERMINE THE
            RECORD NUMBER CONTAINING THE REQUEST TIME, READ IT INTO
            COMMON/TKPTC/, AND PROCEED TO STEP 10 IF IT IS ON THE
            PERMANENT FILE, OR WRITE AN ERROR MESSAGE AND RETURN IF
            IT IS NOT.
        5.  THE ARC IS 20 DAYS OR LESS.  READ THE RECORD CONTAINING
            THE START OF THE ARC INTO THE COMMON ARRAYS, IF IT IS
            PRESENT IN THE PERMANENT FILE, OTHERWISE, WRITE AN ERROR
            MESSAGE AND RETURN.
        6.  THE<21-DAY-ARC TIME SPAN MAY RESIDE ON TWO RECORDS.  CHECK
            IF THE WHOLE ARC IS ON THE RECORD.  IF SO, PROCEED TO
            STEP 10.
        7.  IF THE RECORD CONTAINING THE REST OF THE ARC IS NOT ON
            THE FILE, WRITE AN ERROR MESSAGE AND RETURN.  IF IT IS
            PREPARE TO READ IT BY SLIDING THE DATA PERTAINING TO
            THE FIRST PART OF THE ARC INTO THE STARTING LOCATIONS
            OF ITS ARRAY IN COMMON/TKPTC/.
        8.  READ THE REST OF THE ARC INTO THE LAST LOCATIONS OF THE
            ARRAYS.
        9.  RESET THE STARTING DAY OF THE COMMON BLOCK TO ACCOUNT
            FOR THE SHIFTING.
       10.  EXPAND THE PACKED KP VALUES SO THAT EACH LOCATION IN
            ARRAY KP WILL HAVE ONLY ONE KP NUMBER.
       11.  RETURN TO THE CALLING PROGRAM.


      CALLING SEQUENCE
          CALL JACCWF(T)
          WHERE T IS A TIME AT WHICH A KP AND TC ARE REQUIRED, IN MJD.

CALLING SUBROUTINE:    JACROB

SUBROUTINES CALLED:  OPENMS,READMS,CLOSMS


      COMMON BLOCK VARIABLES

      NAME   DIMEN COMMON I/O DESCRIPTION
      IT       1    TKPTC     TIME OF FIRST DAY OF TC DATA IN COMMON
      KP       21,8TKPTC      MAGNETIC ACTIVITY 3-HOUR INDICES
      TC       20   TKPTC     EXOSPHERIC TEMPERATURE

EXTERNAL DATA SETS USED:
      NAME   LUN   I/O    OPERATION PERFORMED
      KPILE   75   READ   READS THE KP VALUES FROM THE FILE AND
                          STORES THEM IN COMMON TKPTC

 PROGRAMMER
   A.K. KAPOOR ,  COMPUTER SCIENCES CORPORATION
```

Subroutine JACCWF

SUBROUTINE JACROB(RHO,T,P)

PURPOSE

JACROB IS CALLED BY JR TO FURNISH ATMOSPHERIC DENSITY USING JACCHIA'S 1971 ATMOSPHERIC MODEL AS MODIFIED BY ROBERTS IN 1971. COMPUTATIONS PERFORMED ARE TIME DEFINITION, EXOSPHERIC TEMPERATURE, CORRECTIONS TO THE ATMOSPHERIC DENSITY, AND DETERMINATION OF WHICH HEIGHT RANGE TO USE IN COMPUTING THE DENSITY.

METHOD:

1. IF THE SPACECRAFT HEIGHT IS LESS THAN 90KM, SET DENSITY TO ITS VALUE AT 90KM AND RETURN
2. CHECK IF COMMON/TKPTC/ CONTAINS DATA FOR THE TIME IN QUESTION. IF NOT, CALL SUBROUTINE JACCWF TO FILL IT WITH 21 DAYS OF KP AT 3-HOUR INTERVALS (KP(I),J,I=1,21,J=1,8) AND 20 DAYS OF TC(TC(I),I=1,...,20).
3. COMPUTE THE LOCAL TEMPERATURE
4. COMPUTE CORRECTIONS TO THE LOCAL TEMPERATURE DELTA TG) AND TO DENSITY OCCASIONED BY GEOMAGNETIC FLUX.
5. CORRECT THE LOCAL TEMPERATURE FOR GEOMAGNETIC EFFECTS, GIVING THE EXOSPHERIC TEMPERATURE
6. COMPUTE THE INFLECTION POINT TEMPERATURE (TEMPERATURE AT A HEIGHT OF 125KM ABOVE THE SUBSATELLITE POINT).
7. COMPUTE AN ADDITIONAL CORRECTION TO THE DENSITY DUE TO SEMI-ANNUAL VARIATIONS AND ADD IT TO THE CORRECTION TO DENSITY ALREADY COMPUTED
8. COMPUTE THE CORRECTION TO THE DENSITY DUE TO SEASONAL LATITUDINAL VARIATIONS IN THE LOWER THERMOSPHERE, ADDING IT TO THE CORRECTION TO DENSITY ALREADY COMPUTED.
9. CALL THE SUBROUTINES TO COMPUTE UNCORRECTED DENSITY BY ROBERTS FORMULAS:
   IF Z<125KM CALL LOWALT
   IF Z>125KM CALL HIALT
10. CORRECT THE DENSITY
11. CONVERT DENSITY TO MKS UNITS

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
RHO	R	O	THE OUTPUT ATMOSPHERIC DENSITY
T	R	O	TEMPERATURE
P	R	O	PRESSURE

CALLING SUBROUTINE: JR

SUBROUTINES CALLED: JACCWF, HIALT, LOWALT

Subroutine JACROB (1 of 2)

REFERENCES

JACCHIA, L. J., REVISED STATIC MODELS OF THE THERMOSPHERE AND EXOSPHERE WITH EMPIRICAL TEMPERATURE PROFILES, S.A.O., SPECIAL REPORT NO. 332, MAY 5,1971.

ROBERTS, C. E., JR., AN ANALYTICAL MODEL FOR UPPER ATMOSPHERE DENSITIES BASED UPON JACCHIA'S 1970 MODELS, CELESTIAL MECHANICS 4,(1971).

COMMON BLOCK VARIABLES

NAME	DIMEN	COMMON	I/O	DESCRIPTION
DELO	1	JRCOM	O	SUN'S LATITUDE
DTR	1	CONCOM	I	DEGREES TO RADIANS CONVERSION FACTOR
EBASE	1	CONCOM	I	BASE OF NATURAL LOGARITHM
HCJ	1	JRCOM	O	HOUR ANGLE OF THE SUN (DEGREES)
HGT	1	JRCOM	I	SPACECRAFT HEIGHT
IT	1	TKPTC	I	STARTING MJD OF TC VALUES IN THIS COMMON
KP	21,8	TKPTC	I	21 DAYS OF 3-HOUR GEOMAGNETIC INDICES STARTING WITH DAY IT - 1
PHJ	1	JRCOM	O	GEODETIC LATITUDE (RADIANS)
PI	1	CONCOM	I	PI
RHOZ	1	JRCOM	I	ATMOSPHERIC DENSITY AT HEIGHT = ZJO
RTD	1	CONCOM	I	RADIANS TO DEGREES CONVERSION FACTOR
TC	20	TKPTC	I	20 DAYS OF NIGHTTIME MINIMUM GLOBAL EXOSPHERIC TEMPERATURES START ON DAY IT
TINF	1	JRCOM	O	EXOSPHERIC TEMPERATURE
TWOPI	1	CONCOM	I	TWO TIMES PI
TX	1	JRCOM	O	INFLECTION POINT TEMPEATURE
ZJO	1	JRCOM	I	MINIMUM HEIGHT

SUBROUTINES USED

HIALT - COMPUTES RHO AT ALTITUDES ABOVE 125 KM.
JACCWF - FILLS COMMON TKPTC WITH DATA FROM PERMANENT FILE.
LOWALT - COMPUTES RHO AT ALTITUDES BETWEEN 90 KM AND 125 KM

PROGRAMMER

J.P. MOLINEAUX. COMPUTER SCIENCES CORPORATION.

Subroutine JACROB (2 of 2)

```
SUBROUTINE JR(N,POS,TPDW,IERR)

PURPOSE :  JR ROUTINE CONTROLS TEMPERATURE, PRESSURE, AND
           DENSITY CALCULATIONS FOR THE UPPER (JACCHIA-
           ROBERTS) SEGMENT OF THE ATMOSPHERE.

METHOD : 1.  COMPUTE THE JULIAN DATE BY CALLING DELTIM ROUTINE
             AND STORE THE VALUE IN COMMON.
         2.  COMPUTE THE DECLINATION OF THE SUN. STORE IN
             COMMON.
         3.  CALL JACROB SUBROUTINE TO COMPUTE THE TEMPERATURE,
             PRESSURE,AND DENSITY (T,P,D) VALUES.
         4.  STORE VALUES IN ARRAY TPDW.
         5.  RETURN.

ARGUMENT LIST:
  ARGUMENT      TYPE      I/O         DESCRIPTION

   N             I         I         MODEL TYPE
                                     =1, DEFAULT
                                     =2, ADJUSTED
   POS           R         I         FOUR WORD ARRAY
                                     POS(1) --- ALTITUDE(KM)
                                     POS(2) --- LATITUDE(DEG)
                                     POS(3) --- LOCAL SOLAR
                                                TIME (HOURS)
                                     POS(4) --- LONGITUDE
   TPDW          R          O        SEVEN WORD ARRAY
                                     TPDW(1) -- TEMP(DEG KELVIN)
                                         (2) -- PRESSURE(N/M**2)
                                         (3) -- DENSITY(KG/M**3)
                                         (4) -- E-W WIND U(M/SEC)
                                         (5) -- N-S WIND V(M/SEC)
                                         (6) -- WIND SPEED WS(M/SEC)
                                         (7) -- WIND DIRECTION WD
                                                (DEG)
   IERR          I          O        ERROR FLAG

CALLING SUBROUTINES : MODELS, MODADJ

SUBROUTINES CALLED : DELTIM, JACROB

COMMON BLOCKS USED : JRCOM, USECOM, FILCOM

EXTERNAL DATA SETS USED : OUT (DEBUG ONLY)

ANALYST/PROGRAMMER :  A. K. KAPOOR (MATH AND COMPUTING APPLICATION
                      SECTION) COMPUTER SCIENCES CORPORATION
```

Subroutine JR

```
      PROGRAM LAIRS(OUTPUT,OUT,PERM1,WRK,USE,KP,NOIDS,USEMET,
     1TAPE4,TAPE5,TAPE21,TAPE22,TAPE23,
     2TAPE6=OUT,TAPE1=PERM1,TAPE2=WRK,TAPE3=USE,
     3TAPE75=KP,TAPE20=NOIDS,TAPE30=USEMET)

 VERSION 1.2  SEPTEMBER 1981

 PURPOSE:
     LAIRS IS THE MAIN DRIVER FOR THE LANGLEY ATMOSPHERIC
     INFORMATION RETRIEVAL SYSTEM.

 METHOD:
     1. WRITE TO DATA SET NOIDS THE VALUES OF THE COMMON
        BLOCKS SO THAT FOR THE STACKED CASES THE COMMON BLOCKS
        MAY BE RESTORED.
     2. CALL READIN TO PROCESS USER INPUT.
     3. CALL OUTPT TO PRINT THE TITLE PAGE AND RUN INFORMATION.
     4. CALL WFILE TO BUILD THE WORKING FILE.
     5. CALL SETREF TO SET REFERENCE VALUES FROM FILES.
     6. CALL MODADJ IF POLYNOMIAL AND/OR JACCHIA MODEL ADJUSTMENT
        IS REQUIRED.
     7. CALL PARAMS TO CALCULATE THE ATMOSPHERIC PROFILE.
     8. CALL OUTPT1 TO CONCLUDE THE PRINTOUT.
     9. IF REQUIRED, CALL PREUSE TO CREATE A METEOROLOGICAL FILE
        FROM THE OUTPUT USER FILE.
    10. REWIND FILES AND INITIALIZE COMMON FOR STACKED DECK CASE.
    11. STOP.

 ARGUMENT LIST: NONE

 CALLING SUBROUTINES: NONE

 SUBROUTINES CALLED: READIN,OUTPT,SETREF,MODADJ,PARAMS,
                     OUTPT1,PREUSE
```

Program LAIRS (1 of 2)

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	MODL	I	LOWER ATMOSPHERE MODEL TYPE
	MODU	I	UPPER ATMOSPHERE MODEL TYPE
	ICRT	I	METEOROLOGICAL FILE CREATION FLAG
/FILCOM/	LINES	I	LINE COUNTER
	NPRM	I	PERMANENT FILE LUN
	NWRK	I	WORKING FILE LUN
	MWF1	I	METEOROLOGICAL FILE 1 LUN
	MWF2	I	METEOROLOGICAL FILE 2 LUN
	MWF3	I	METEOROLOGICAL FILE 3 LUN
	NENT	I	ENTREE (BET) FILE LUN
	NOIDS	I	SAVE FILE LUN
	NUSE	I	USER FILE LUN

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
PERM	NPRM	REWIND
WORK	NWRK	REWIND
MET1	MWF1	REWIND
MET2	MWF2	REWIND
MET3	MWF3	REWIND
ENT	NENT	REWIND
USE	NUSE	REWIND
NOIDS	NOIDS	WRITE,READ,REWIND

PROGRAMMER: D. E. BOLAND, CSC, MARCH 1981

Program LAIRS (2 of 2)

```
    SUBROUTINE LAP(NZ,ZNEXT)

PURPOSE:
    LAP GENERATES ALTITUDE POINTS ON THE LOCAL ATMOSPHERIC PROFILE.

METHOD:
    1. COMPUTE LOCAL SOLAR TIME OF PROFILE.
    2. CALCULATE ALL Z VALUES NEEDED.
    3. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    NZ        I      I     NUMBER OF POINTS IN BLOCK
    ZNEXT     I     I/O    NEXT Z VALUE TO BE COMPUTED

CALLING SUBROUTINE: PARAMS

SUBROUTINES CALLED:  RLST

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       THETA      I     LATITUDE
                  TAU        I     LONGITUDE
                  Z1         I     LOWER ALTITUDE FOR LAP
                  Z2         I     UPPER ALTITUDE FOR LAP
                  DZ         I     ALTITUDE INTERVAL
   /CALCOM/       TRJ(5,10)  O     BLOCK OF TRAJECTORY POINTS:
                                    Z,LAT,LONG,GMT,LST

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC,      MARCH 1981
```

Subroutine LAP

```
SUBROUTINE LATADJ(NF,F,A1,P1,A2,P2,DFLAT,TAU,RLAT)

PURPOSE:
    LATADJ COMPUTES NEW LATITUDE GRADIENTS FOR ANY INPUT
    PARAMETER F (T,P, OR D) FROM METEOROLOGICAL DATA.

METHOD:
    1. TRANSLATE EACH INPUT PARAMETER F (UP TO 3 POINTS --
       ONE FROM EACH MET FILE) FROM ITS LOCAL SOLAR TIME TAU
       TO THE MODEL REFERENCE LOCAL SOLAR TIME REFTAU TO
       REMOVE THE DIURNAL/SEMIDIURNAL COMPONENT OF THE
       VARIATION OF F.
    2. COMPUTE THE LATITUDE GRADIENT OF F FROM THE TRANSLATED
       VALUES OF F BY THE METHOD OF LEAST SQUARES. LATITUDE
       UNITS ARE DEGREES.
    3. RETURN.

ARGUMENT LIST:
ARGUMENT   TYPE   I/O   DESCRIPTION
    NF       R     I     NUMBER OF POINTS OF F
    F        R     I     PARAMETER TO BE TRANSLATED
    A1       R     I     DIURNAL AMPLITUDE OF F
    P1       R     I     DIURNAL PHASE OF F
    A2       R     I     SEMIDIURNAL AMPLITUDE OF F
    P2       R     I     SEMIDIURNAL PHASE OF F
    TAU      R     I     LOCAL SOLAR TIME OF MET PROFILE
    DFLAT    R     O     LATITUDE GRADIENT OF F
    RLAT     R     I     LATITUDE OF MET PROFILE

CALLING SUBROUTINE: TRNADJ

SUBROUTINES CALLED: TRNDSD

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       REFLAT      I    MODEL REFERENCE LATITUDE
                  REFTAU      I    MODEL REFERENCE LOCAL SOLAR TIME
                  IHSDA       I    FLAG FOR D/SD ADJUSTMENT

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC,     MARCH 1981
```

Subroutine LATADJ

```
SUBROUTINE LOWALT(RHO,T,P)

PURPOSE
  LOWALT IS CALLED BY JACROB TO FURNISH ATMOSPHERIC DENSITY VALUES
  AT AND BELOW 125 KM.
 THIS SUBROUTINE SELECTS BETWEEN SUBROUTINE BARODE AND DIFFDE
 FOR COMPUTING THE UNCORRECTED DENSITY, DEPENDING ON WHETHER
 THE SATELLITE IS BELOW OR ABOVE 100KM.

METHOD:
   1.  EVALUATE CONSTANTS
   2.  CALL SUBROUTINE ROOTS TO COMPUTE THE ROOTS R1,R2,
       X+IY, AND X-IY OF THE POLYNOMIAL
   3.  COMPUTE THE CONSTANTS NEEDED BY BARODE AND DIFFDE
   4.  COMPUTE THE TEMPERATURE AT THE SATELLITE
   5.  IF Z<100KM, CALL BARODE;
       IF Z>100KM, COMPUTE THE TEMPERATURE AT 100KM AND
       CALL DIFFDE

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O     DESCRIPTION
  RHO          R       O      RHO IS A PARTIAL ATMOSPHERIC DENSITY
  T            R       O      TEMPERATURE
  P            R       O      PRESSURE

CALLING SUBROUTINE:   JACROB

SUBROUTINES CALLED:
     BARODE  COMPUTE RHO BETWEEN 90 AND 100 KM
     DIFFDE  COMPUTE RHO BETWEEN 100 AND 125 KM
     ROOTS   TO COMPUTE THE ROOTS OF THE POLYNOMIAL

COMMON BLOCK VARIABLES
NAME      DIMEN     COMMON I/O DESCRIPTION
CC          5        JRCOM  I   POWER SERIES COEFFICIENTS FOR TZ
DUM1        1        JRCOM I/O  IMMAGINARY PART OF RL1
DUM2        1        JRCOM I/O  IMMAGINARY PART OF RL2
FKL         1        JRCOM  I   FACTOR INVOLVED IN RHO COMPUTATION
FLC4        1        JRCOM  I   MODIFYING FACTOR
GLO.        1        JRCOM  I   MEAN SURFACE GRAVITY
HGT         1        JRCOM  I   HEIGHT OF SPACECRAFT
RC          1        JRCOM  I   UNIVERSAL GAS CONSTANT
RCM         1        JRCOM  I   AVERAGE EARTH RADIUS
RL1         1        JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND
RL2         1        JRCOM  I   ROOT OF POLFNOMIAL IN INTEGRAND
TCIL        1        JRCOM  I   TEMPERATURE AT 100 KM.
TX          1        JRCOM  I   INFLECTION POINT TEMPERATURE
TZ          1        JRCOM  I   TEMPERATURE AT HEIGHT Z
TO          1        JRCOM  I   TEMPERATURE AT MINIMUM HEIGHT
UC          2        JRCOM  I   FUNCTIONAL VALUES AT RL1 AND RL2
VCDI        1        JRCOM  I   FACTOR INCLUDEDIN RHO COMPUTATION
WC          2        JRCOM  I   FUNCTIONAL VALUES AT RL1 AND RL2
XCDI        1        JRCOM  I   FACTOR INCLUDEDIN RHO COMPUTATION
XLPS        1        JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND
YLPS        1        JRCOM  I   ROOT OF POLYNOMIAL IN INTEGRAND

PROGRAMMER
  A. K. KAPOOR , COMPUTER SCIENCES CORPORATION
```

Subroutine LOWALT

```
    SUBROUTINE METINT(NM,POS,TPDWM,TPDWMU,IERR)

PURPOSE:
    METINT IS THE EXECUTIVE SUBROUTINE FOR CONTROLING METEOROLO-
    GICAL INTERPOLATION FOR TEMPERATURE, PRESSURE, DENSITY, AND
    WIND COMPONENTS.

METHOD:
    1. CALL METIN1 TO OBTAIN INTERPOLATED VALUES FOR T, P, D,
       U, AND V IN ALTITUDE FOR EACH MET. PROFILE PROVIDED.
    2. PERFORM UNIVARIATE OR BIVARIATE INTERPOLATION FOR T, P, D, U,
       AND V BETWEEN THE TWO OR THREE MET. PROFILES PROVIDED.
    3. RETURN.

ARGUMENT LIST:
   ARGUMENT   TYPE   I/O   DESCRIPTION
     NM         I     I     ATMOSPHERIC SEGMENT,
                              =0, FLAG FOR CALL FROM SETREF
                              =1, UPPER SEGMENT
                              =2, LOWER SEGMENT
     POS        R     I     4-WORD ARRAY FOR TRAJECTORY POINT:
                              POS(1)=ALTITUDE
                              POS(2)=LATITUDE
                              POS(3)=LOCAL SOLAR TIME
                              POS(4)=LONGITUDE
     TPDWM      R     O     CALCULATED ATMOSPHERIC PARAMETERS:
                              TPDWM(1)=TEMPERATURE
                              TPDWM(2)=PRESSURE
                              TPDWM(3)=DENSITY
                              TPDWM(4)=E-W WIND , U
                              TPDWM(5)=N-S WIND , V
                              TPDWM(6)=WIND SPEED , WS
                              TPDWM(7)=WIND DIRECTION , WD
     TPDWMU     R     O     UNCERTAINTIES IN PARAMETERS (7)
     IERR       I     O     ERROR FLAG:
                              =0, NO ERROR
```

Subroutine METINT (1 of 2)

CALLING SUBROUTINES: MODELS

SUBROUTINES CALLED: METIN1,DFLINT, IBI, TRNLAT, TRNDSD

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/FILCOM/	NPRINT	I	PRINTER OUTPUT LUN
/USECOM/	INTP	I	ALTITUDE INTERPOLATION USED
	INT	I	METEOROLOGICAL INTERPOLATION USED =0, UNIVARIATE =1, 1ST ORDER BIVARIATE =2, 2ND ORDER BIVARIATE
	NFILE	I	NUMBER OF MET. PROFILES
	BOUND	I	BOUNDARY BETWEEN UPPER AND LOWER ATMOSPHERIC SEGMENTS
	RMGMT	I	GMT FOR EACH MET. PROFILE
/INTCOM/	II	I	POINTER USED IN ARRAY ARR
	ARR	I	ARRAY OF COEFFICIENTS, INCLUDING LATITUDE GRADIENTS
/METCOM/	RLAT	I	ARRAY FOR LATITUDES OF MET. FILES
	RLONG	I	ARRAY FOR LONGITUDES OF MET FILES
	RLSTM	I	LST FOR EACH MET. PROFILE

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE

PROGRAMMER: R.A. KUSESKI, COMPUTER SCIENCES CORP.

Subroutine METINT (2 of 2)

```
    SUBROUTINE METIN1(ALT,TPDW,TPDWMU,NFILRD,IERR1)

PURPOSE:
    METIN1 READS THE GIVEN METEOROLOGICAL PROFILES AND INTERPOLATES
    THEM IN ALTITUDE FOR T, P, D, U, V.

METHOD:
    1. READS EACH MET. PROFILE IN SEQUENCE AND STORES VALUES IN
       ARRAYS.
    2. CALLS IUNI TO INTERPOLATE ARRAYS IN ALTITUDE.
    3. USES LOGARITHMIC INTERPOLATION FOR PRESSURE AND DENSITY.
    4. DETERMINES LARGEST UNCERTAINTY FOR EACH PARAMETER.
    5. RETURNS.

ARGUMENT LIST:
   ARGUMENT    TYPE    I/O    DESCRIPTION
     ALT        R       I      TRAJECTORY ATLITUDE
     TPDW       R       O      5-WORD ARRAY WITH T,P,D,U,V
                                FOR EACH PROFILE
     TPDWMU     R       O      UNCERTAINTIES IN T,P,D,U,V
     NFILRD     I       O      FLAG FOR READING MET. PROFILE
                                  =0, FILE READ
                                  =1, EOF OR EXTRAPOLATION IN ATL.
     IERR1      I       O      ERROR FLAG

CALLING SUBROUTINES:  METINT, TRNADJ

SUBROUTINES CALLED:  IUNI

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       INPT       I     ALTITUDE INTERPOLATION FLAG
                                     =1, 1ST ORDER LAGRANGE
                                     =2, 2ND ORDER LAGRANGE
                  IDBG       I     DEBUG FLAG
                  NFILE      I     NUMBER OF MET. PROFILES
   /FILCOM/       NPRINT     I     PRINTED OUTPUT LUN
                  METLUN     I     FIRST MET. PROFILE INPUT LUN
   /METCOM/       IPT        I     POINTER USED IN IUNI
                  METFLG     I     FLAG FOR 1ST CALL TO METIN1
                  II         I     POINTER TO CLOSEST ALTITUDE
                                    IN DATA ARRAR (METARR)
                  ALTM       I     ARRAY OF ALTITUDES FOR EACH
                                    PROFILE
                  METARR     I     ARRAY OF T,P,D, AND WIND SPEED
                                    AND DIRECTION FOR EACH FILE
                  FSTPT      I     LOWEST ALTITUDE FOR EACH FILE
                  RLAT       I     LATITUDE OF EACH PROFILE
                  RLONG      I     LONGITUDE OF EACH PROFILE

EXTERNAL DATA SETS USED:
       NAME           LUN        I/O OPERATIONS PERFORMED
       MET1           METLUN      READ
       MET2           METLUN+1    READ
       MET3           METLUN+2    READ
       OUT            NPRINT      WRITE

PROGRAMMER:  R.A. KUSESKI, COMPUTER SCIENCES CORP.
```

Subroutine METIN1

```
      SUBROUTINE METREF(ISEG,NMET,Z,T,P,D,WT,WP,WD,IERR)

PURPOSE:
      METREF PRODUCES A SINGLE REFERENCE METEOROLOGICAL PROFILE
      (1 SEGMENT AT A TIME) FROM THE INPUT METEOROLOGICAL PROFILES.

METHOD:
      1. READ THE POINTS IN SEGMENT ISEG OF THE NEXT PROFILE.
      2. CALCULATE THE WEIGHTING FACTORS FOR EACH POINT.
      3. IF TRANSLATION IS REQUIRED, CALL DFLINT TO OBTAIN
         TRANSLATIONAL COEFFICIENTS AND CALL TRNLAT AND TRNDSD
         TO PERFORM TRANSLATION.
      4. CALCULATE THE LOG BASE E OF PRESSURE AND DENSITY.
      5. REWIND THIS METEOROLOGICAL PROFILE.
      6. REPEAT STEPS 1-5 FOR THE NEXT PROFILE UNLESS ALL PROFILES
         HAVE BEEN PROCESSED.
      7. RETURN.

ARGUMENT LIST:
   ARGUMENT   TYPE   I/O   DESCRIPTION
      ISEG      I      I     ATMOSPHERIC SEGMENT NUMBER
      NMET      I      I     NUMBER OF POINTS IN  THIS SEGMENT
      Z         R      I     ALTITUDE ARRAY
      T         R      I     TEMPERATURE ARRAY
      P         R      I     PRESSURE ARRAY
      D         R      I     DENSITY ARRAY
      WT        R      I     TEMPERATURE WEIGHTS
      WP        R      I     PRESSURE WEIGHTS
      WD        R      I     DENSITY WEIGHTS
      IERR      I      O     ERROR FLAG

CALLING SUBROUTINE: POLADJ

SUBROUTINES CALLED: DFLINT
```

Subroutine METREF (1 of 2)

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	ILATL	I	FLAG FOR LATITUDE VARIATIONS
	IDSDL	I	FLAG FOR D/SD VARIATIONS
	IWL	I	WIND FLAG
	NFIL	I	NUMBER OF MET FILES
	BOUND	I	3 SEGMENT BOUNDARIES
	RMERGE	I	REGION FOR SEGMENT MERGING
	REFLAT	I	REFERENCE LATITUDE
	REFTAU	I	REFERENCE LOCAL SOLAR TIME
	RMGMT	I	GMT OF MET FILES
/INTCOM/	I2	I	FLAG TO REINITIALIZE DFLINT
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
	WRK	I	WORKING FILE LUN
	MWF	I	METEOROLOGICAL FILES LUNS
/DCCOM/	WTDCT	I	A PRIORI TEMPERATURE WEIGHTING
	WTDCP	I	A PRIORI PRESSURE WEIGHTING
	WTDCD	I	A PRIORI DENSITY WEIGHTING

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE (DEBUG ONLY)
WRK	NWRK	REWIND
MET1	MWF(1)	READ, REWIND
MET2	MWF(2)	READ, REWIND
MET3	MWF(3)	READ, REWIND

PROGRAMMER: D. E. BOLAND, CSC

Subroutine METREF (2 of 2)

```
    SUBROUTINE MODADJ(IERR)

PURPOSE:
    MODADJ IS THE MODEL ADJUSTMENT EXECUTIVE.

METHOD:
    1. CALL POLADJ IF POLYNOMIAL MODEL ADJUSTMENT IS REQUIRED.
    2. RESET JACCHIA-ROBERTS MODEL DENSITY BOUNDARY VALUES AT
       90, 100, AND 125 KILOMETERS.  (NOTE THIS PROCEDURE REPLACES
       THE FIRST 10 WORDS OF THE ARRAY DD(35) IN JRCOM WITH THE
       ARRAYS FD125(5) AND D125(5)).
    3. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    IERR      I      O     ERROR FLAG:
                            =0, NO ERROR

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED:  POLADJ, JR

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       MODL       I     TYPE OF LOWER ATMOSPHERIC MODEL
                  MODU       I     TYPE OF UPPER ATMOSPHERIC MODEL
                  IDBG       I     DEBUG FLAG
                  BOUND1     I     TOP SEGMENT BOUNDARY (KM)
   /JRCOM/        FD125      I     INDIVIDUAL NUMBER DENSITIES
                                    AT 125 KM
                  D125       O     LOG INDIVIDUAL NUMBER DENSITIES
                                    AT 125 KM
                  AVG        I     AVOGADRO'S NUMBER
                  DBOUND    I/O    DENSITY VALUE AT BOUND1
                  ZD        I/O    COEFFICIENTS FOR DENSITY AT 100 KM

EXTERNAL DATA SETS USED:
      NAME          LUN       I/O OPERATIONS PERFORMED
      OUT           NPRINT     WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC
```

Subroutine MODADJ

```
    SUBROUTINE MODELS(POS,UPOS,TPDW,UTPDW,IERR)

PURPOSE:
    MODELS CONTROLS THE COMPUTATION OF TEMPERATURE T, PRESSURE P,
    DENSITY D, AND WINDS U, V AND WS, WD FOR EACH POINT ON
    A SHUTTLE TRAJECTORY OR A LOCAL ATMOSPHERIC PROFILE.

METHOD:
    1. DETERMINE IF THE CURRENT POINT IS IN THE UPPER OR THE
       LOWER ATMOSPHERE.
    2. BRANCH TO THE APPROPRIATE CALCULATION ROUTINE ON THE BASIS
       OF FLAGS SET BY THE USER.
    3. COMPUTE WINDS FOR NON-INTERPOLATION MODELS.
    4. RETURN.

ARGUMENT LIST:
   ARGUMENT   TYPE   I/O   DESCRIPTION
     POS       R      I     TRAJECTORY POINT:
                             POS(1)=ALTITUDE
                             POS(2)=LATITUDE
                             POS(3)=LOCAL SOLAR TIME
                             POS(4)=LONGITUDE
     UPOS      R      I     UNCERTAINTIES IN TRAJECTORY POINT (3)
     TPDW      R      O     CALCULATED ATMOSPHERIC PARAMETERS:
                             TPDW(1)=TEMPERATURE
                             TPDW(2)=PRESSURE
                             TPDW(3)=DENSITY
                             TPDW(4)=E-W WIND U
                             TPDW(5)=N-S WIND V
                             TPDW(6)=WIND SPEED WS
                             TPDW(7)=WIND DIRECTION WD
     UTPDW     R      O     UNCERTAINTIES IN PARAMETERS (7)
     IERR      I      O     ERROR FLAG:
                             =0, NO ERROR

CALLING SUBROUTINE: PARAMS

SUBROUTINES CALLED: DFLINT,METINT,JR,POLY,WIND,WCNVRT

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       MODL       I     LOWER ATMOSPHERE MODEL TYPE
                  MODU       I     UPPER ATMOSPHERE MODEL TYPE
                  IDBG       I     DEBUG FLAG
                  BOUND      I     UPPER-LOWER ATMOSPHERE BOUNDARY
   /FILCOM/       NPRINT     I     PRINTED OUTPUT LUN

EXTERNAL DATA SETS USED:
      NAME        LUN       I/O OPERATIONS PERFORMED
      OUT         NPRINT    WRITE(DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC,      MARCH 1981
```

Subroutine MODELS

```
      SUBROUTINE NLSPOL(ISEG,KS,NMET,ZMET,TMET,DMET,PMET,TW2,DW2,PW2,
     *ZBOUND,PBOUND,SUM,E,B,IERR)
```

PURPOSE
NLSPOL IS THE EXECUTIVE OF THE NON-LINEAR LEAST-SQUARE FITTING PROCEDURE

METHOD:
THE SUM OF THE WEIGHTED SQUARED RESIDUALS IS MINIMIZED ITERATIVELY.

1. COMPUTE WEIGHTED RESIDUALS
2. COMPUTE TEMPERATURE,PRESSURE, AND DENSITY PARTIAL DERIVATIVES
3. CONSTRUCT NORMAL MATRIX
4. INVERT THE NORMAL MATRIX AND COMPUTE THE CORRECTIONS TO THE SOLVE-FOR PARAMETERS
5. RETURN

ARGUMENT LIST

ARGUMENT	TYPE	I/O	DESCRIPTION
ISEG	I	I	SEGMENT NUMBER
KS	I	I	CONTROLS THE NUMBER OF SOLVE-FOR PARAMETERS =1 SOLVES FOR ALL TEMP. COEFS AND PBOUND =2 SOLVES FOR TEMP. COEFS WITH BOUNDARY TEMP. AND PBOUND FIXED =3 SOLVES FOR ALL TEMP. COEFS WITH PBOUND FIXED =4 SOLVES FOR ALL PARAMETERS WITH BOUNDARY TEMP. FIXED
NMET	I	I	NUMBER OF MET. ALTITUDE POINTS
ZMET	R	I	ALTITUDE ARRAY OF MET. DATA
TMET	R	I	MET. TEMPERATURE DATA
DMET	R	I	LOG OF MET. DENSITY
PMET	R	I	LOG OF MET. PRESSURE
TW2	R	I	SQUARED WEIGHT FOR TEMPERATURE
DW2	R	I	SQUARED WEIGHT FOR LOG DENSITY
PW2	R	I	SQUARED WEIGHT FOR LOG PRESSURE
ZBOUND	R	I	BOUNDARY ALTITUDE
PBOUND	R	I	PRESSURE AT ZBOUND
SUM	R	O	SUM OF SQUARED WEIGHTED RESIDUALS
E	R	O	VARIANCE-COVARIANCE MATRIX
B	R	I/O	TEMPERATURE COEFS
IERR	I	O	ERROR FLAG

CALLING SUBROUTINES: POLFIT

Subroutine NLSPOL (1 of 2)

SUBROUTINES CALLED: TPAR, DPAR, PPAR, SOLVE, SIMP, OUTRES, OUTDC

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	ITRMAX	I	MAX. NUMBER OF ITERATIONS
	KTMET	I	=0 USE TEMPERATURE DATA =1 DO NOT USE TEMPERATURE DATA
	KPMET	I	=0 USE PRESSURE DATA =1 DO NOT USE PRESSURE DATA
	KDMET	I	=0 USE DENSITY DATA =1 DO NOT USE DENSITY DATA
	RSTEP	I	STEP SIZE FOR INTEGRATION
	EPSCON	I	CONVERGENCE CRITERIA
	RMSZRO	I	INITIAL RMS
	RMSADD	I	RMS ADDER
	FSIGMA	I	MULTIPLYING FACTOR TO RMS FOR EDITTING
/SOLAND/	KINT	I	NUMBER OF INTEGRALS
	KSOLA4	I	=0 NOT SOLVES FOR BOUNDARY TEMP. =1 SOLVES FOR BOUNDARY TEMP.
	KSOLA5	I	=0 NOT SOLVES FOR BOUNDARY PRESSURE =1 SOLVES FOR BOUNDARY PRESSURE
	NPOL	I	ORDER OF POLYNOMIALS FOR TEMP.
	MAXSOL	I	MAX. NUMBER OF SOLVE-FOR PARAMETERS
	NSOLV	O	NUMBER OF SOLVE-FOR PARAMETERS
	KEDTOT	O	TOTAL NUMBER OF MET. DATA USED
	KONVRG	O	CONVERGENCE FLAG
	ZREF	I	SEGMENT BOUNDARY (ZBOUND)
	EPSLON	I	CONVERGENCE CRITERIA (EPSCON)
	SRSUM	O	TOTAL SUM OF SQUARED WEIGHTED RESIDUALS
	CURRMS	O	CURRENT RMS
	OLDRMS	O	PREVIOUS RMS
	RMSP	O	PREDICTED RMS
	A	I/O	SOLVE-FOR PARAMETER ARRAY
	G	O	RIGHT HAND SIDE OF NORMAL EQU.
	SH	O	LINEAR ARRAY OF NORMAL MATRIX
/JRCOM/	RE	I	MEAN RADIUS OF THE EARTH
	RSTAR	I	UNIVERSAL GAS CONSTANT
	GS	I	GRAVITATIONAL ACC. AT THE SURFACE OF THE EARTH
	XM	I	MEAN MOLECULAR WEIGHT

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE (DEBUG ONLY)

PROGRAMMER: T. LEE, CSC MARCH 1981

Subroutine NLSPOL (2 of 2)

```
    SUBROUTINE OUTDC(ISEG,ITER,NMET,KTT,KDT,KPT,KONVRG,KSOLA4,
   *KSOLA5,CURRMS,OLDRMS,RMSP,APA,A,DEL,VCMAT)

PURPOSE:
    OUTDC PRODUCES A DIFFERENTIAL CORRECTION RUN SUMMARY

ARGUMENT LIST:
 ARGUMENT  TYPE  I/O   DESCRIPTION
  ISEG      I     I    =2 UPPER SEGMENT
                       =3 MIDDLE SEGMENT
                       =4 LOWER SEGMENT
  ITER      I     I    ITERATION NUMBER
  NMET      I     I    NUMBER OF METEOROLOGICAL DATA
  KTT       I     I    TOTAL NUMBER OF TEMP. DATA USED
  KDT       I     I    TOTAL NUMBER OF DENSITY DATA USED
  KPT       I     I    TOTAL NUMBER OF PRESSURE DATA USED
  KONVRG    I     I    CONVERGENCE FLAG
                       =1 CONVERGED
                       =2 CONVERGING
                       =3 DIVERGING
                       =4 CONVERGED: LINEAR FITTING
  KSOLA4    I     I    =0 DOES NOT SOLVE FOR BOUNDARY TEMP.
  KSOLA5    I     I    =0 DOES NOT SOLVE FOR BOUNDARY PRESSURE
  CURRMS    R     I    CURRENT WEIGHTED RMS
  OLDRMS    R     I    PREVIOUS WEIGHTED RMS
  RMSP      R     I    PREDICTED RMS
  APA       R     I    A PRIORI SOLVE-FOR PARAMETERS
  A         R     I    CURRENT VALUES OF SOLVE-FOR PARAMETERS
  DEL       R     I    CORRECTION : CURRENT - PREVIOUS
  VCMAT     R     I    VARIANCE-COVARIANCE MATRIX

CALLING SUBROUTINE: NLSPOL

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /FILCOM/       NPRINT     I     PRINTED OUTPUT LUN
                  IPAGE      I     PAGE COUNTER

EXTERNAL DATA SETS USED:
  NAME          LUN         I/O OPERATIONS PERFORMED
   OUT         NPRINT        WRITE

PROGRAMMER: A. K. KAPOOR, T. LEE, CSC   MARCH 1981
```

Subroutine OUTDC

```
    SUBROUTINE OUTPRF(IPRFL,NZ)

PURPOSE:
  SUBROUTINE OUTPRF GENERATES A BLOCK PRINTOUT OF THE
  ATMOSPHERIC PARAMETERS.

METHOD:
   1. PRINT HEADER AND COLUMN HEADINGS.
   2. PRINT BLOCK OF DATA (10 TRAJECTORY POINTS).
   3. WRITE USER FILE.
   4. RETURN.

ARGUMENT LIST :
  ARGUMENT  TYPE  I/O  DESCRIPTION
    IPRFL     I     I     TYPE OF DATA; 1=ENTREE,2=LAP
    NZ        I     I     NUMBER OF POINTS IN BLOCK

CALLING SUBROUTINES : PARAMS

SUBROUTINES CALLED : NONE

COMMON BLOCK PARAMETERS USED :
  COMMON NAME   PARAMETER   I/O    DESCRIPTION
   /CALCOM/       TRJ        I      10 TRAJECTORY POINTS:
                                      ALT,LAT,LONG,GMT, AND LST
                  UTRJ       I      UNCERTAINTIES IN ALT,LAT,LONG,
                                      GMT, AND LSTI
                  TPDW       I      7-WORD ARRAY: T,P,D,U,V,WS,AND WD
                  UTPDW      I      UNCERTAINTIES IN T,P,D,U,V,WS,
                                      AND WD
                  WTMOL      I      MEAN MOLECULAR WEIGHT (10)
                  SCHT       I      PRESSURE SCALE HEIGHT (10)
                  RMACH      I      MACH NUMBER (10)
                  OBPRES     I      ON-BOARD PRESSURE (10)
                  PCDEV      I      PERCENT DEVIATION FROM GAS LAW(10)
   /FILCOM/       NPRINT     I      PRINTED OUTPUT LUN
                  NUSE       I      USER FILE LUN
                  LINES     I/O     LINE COUNTER
                  IPAGE     I/O     NUMBER OF PAGES PRINTED

EXTERNAL DATA SETS USED :
      NAME          LUN      I/O OPERATIONS PERFORMED
      OUT           NPRINT    WRITE
      USE           NUSE      WRITE

PROGRAMMER :  R.A. KUSESKI  CSC,      MARCH 1981
```

Subroutine OUTPRF

```
    SUBROUTINE OUTPT(IERR)

PURPOSE:
   OUTPT WRITES THE INITIAL CONDITIONS REPORT

METHOD:
   1. PRINTS HEADER AND OPTIONS CHOSEN FOR THE LOWER AND UPPER
      ATMOSPHERE.
   2. PRINTS DESCRIPTION OF OUTPUT PARAMETERS WITH UNITS.
   3. RETURN.

ARGUMENT LIST:
   ARGUMENT   TYPE   I/O   DESCRIPTION
     IERR      I      I     ERROR FLAG

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       IPRFL      I     TYPE OF PROFILE
                  MODL       I     TYPE OF LOWER ATMOSPHERIC MODEL
                  IWL        I     TYPE OF L.A. WIND MODEL
                  ILATL      I     LATITUDE VARIATIONS IN L.A.
                  IDSDL      I     DIURNAL/SEMIDIURNAL VARIATIONS, L.A.
                  MODU       I     TYPE OF UPPER ATMOSHPHERIC MODEL
                  IWU        I     TYPE OF U.A. WIND MODEL
                  ILATU      I     LATITUDE VARIATIONS IN U.A.
                  IDSDU      I     DIURNAL/SEMIDIURNAL VARIATIONS, U.A.
                  IPHYS      I     DERIVE PRESSURE AND DENSITY FROM
                                    TEMPERATURE VIA PHYSICAL LAWS
                                    (OVERRIDES ALL OTHER SELECTIONS)
                  INTP       I     INTERPOLATOR TYPE - ALTITUDE ONLY
                  IDBG       I     PRINT DEBUG
                  INT        I     INTERPOLATER TYPE - BETWEEN
                                                  MET. PROFILES
                  IDNUM      I     ENTREE-LAP ID NUMBER
                  IGAS       I     GAS LAW CALCULATION FLAG
                  IDC        I     DIFFERENTIAL CORRECTION FLAG
                  NPTSE      I     NUMBER OF POINTS IN ENTREE FILE
                  NSAMP      I     SAMPLE RATE FOR ENTREE FILE
                  YMD        I     YEAR, MONTH, DAY OF LAP OR ENTREE
                                    TRAJECTORY
   /FILCOM/       NPRINT     I     PRINTED OUTPUT LUN
                  NUSE       I     USER FILE LUN
                  IPAGE     I/O    NUMBER OF PAGES PRINTED

EXTERNAL DATA SETS USED:
      NAME          LUN       I/O OPERATIONS PERFORMED
      OUT           NPRINT     WRITE
      USE           NUSE       WRITE

PROGRAMMER:  R.A. KUSESKI, CSC,      MARCH 1981
```

Subroutine OUTPT

```
     SUBROUTINE OUTPT1(IERR)

 PURPOSE:
    OUTPT1 WRITES THE SECOND HALF OF THE OUTPUT PARAMETERS REPORT
    AND THE ERROR SUMMARY INFORMATION.

 METHOD:
    1. READS USER FILE AND PRINTS DESIRED INFORMATION
    2. WRITES ERROR RETURN SUMMARY INFORMATION
    3. RETURNS

 ARGUMENT LIST:
    ARGUMENT LIST:
    ARGUMENT    TYPE    I/O    DESCRIPTION
      IERR       I       I      ERROR FLAG

 CALLING SUBROUTINE: LAIRS

 SUBROUTINES CALLED: NONE

 COMMON BLOCK PARAMETERS USED:
    COMMOM NAME   PARAMETER   I/O   DESCRIPTION
     /FILCOM/       NPRINT     I     PRINTER OUTPUT LUN
                    NUSE       I     USER FILE LUN
                    LINES     I/O    LINE COUNTER
                    IPAGE     I/O    PAGE COUNTER

 EXTERNAL DATA SETS USED:
       NAME           LUN      I/O OPERATIONS PERFORMED
       OUT            NPRINT    WRITE
       USE            NUSE      READ

 PROGRAMMER:  R.A. KUSESKI, COMPUTER SCIENCES CORPORATION, JULY 1981
```

Subroutine OUTPT1

SUBROUTINE OUTRES (ISEG,I1,I2,NMET,Z,Y,WT,RESID,SUM,IEDIT)

PURPOSE:
TO OUTPUT A RESIDUALS REPORT FOR A LAIRS LINEAR OR NONLINEAR PROGRAM RUN

METHOD:
ALL THE INFORMATION THAT HAS TO BE REPORTED IS PASSED THROUGH THE ARGUMENT LIST. THE INFORMATION INVOLVED IS THE SEGMENT NUMBER, WHAT TYPE OF DATA IS BEING OUTPUT (TEMPERATURE, PRESSURE, OR DENSITY) THE ITERATION NUMBER, NUMBER OF POINTS, ALTITUDE, OBSERVED VALUES, WEIGHT OF RESIDUALS, RMS, AND THE EDITING CRITERIA FLAGS.

THIS INFORMATION IS PARTITIONED IN ELEVEN COLUMNS AND OUTPUT IN A UNIFORM FORMAT.

ARGUMENT LIST:

VARIABLE	TYPE	DIMENSION	DESCRIPTION
ISEG	I	1	SEGMENT NUMBER FLAG I.E., UPPER, MIDDLE, OR LOWER
I1	I	1	TEMPERATURE, PRESSURE, OR DENSITY FLAG
I2	I	1	RUN TYPE AND ITERATION NUMBER FLAG =0, LINEAR RUN AND ONLY ONE REPORT IS PRINTED = ITER # , NONLINEAR RUN AND THIS FLAG IS THE ITERATION NUMBER
NMET	I	NMET	NUMBER OF POINTS
Z	R	Z(NMET)	ALTITUDE RELATED TO N TH POINT
Y	R	Y(NMET)	OBSERVED VALUE OF TEMPERATURE, PRESSURE, OR DENSITY
WT	R	WT(NMET)	WEIGHTS ASSOCIATED WITH N TH POINT
RESID	R	(NMET)	RESIDUALS FOR THE N TH POINT
SUM	R	1	THE RMS
IEDIT	I	(NMET)	EDITING FLAG FOR THE N TH POINT

CALLING ROUTINES: NLSPOL,POLFIT

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS :

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/FILCOM/	NOUT	I	PRINTED OUTPUT LUN
	IPREV	I	ITERATION NO. OF LAST ITERATION
	NUMLIN	I	LINE COUNTER
	IPAGE	I	PAGE COUNTER

EXTERNAL DATA SETS USED :

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NOUT	WRITE

PROGRAMMER/ANALYST : A. K. KAPOOR   COMPUTER SCIENCES CORPORATION

Subroutine OUTRES

SUBROUTINE OUTSUM(IA)

PURPOSE:

OUTSUM PRODUCES A SUMMARY REPORT OF THE SOLVED-FOR COEFFICIENTS FOR A LINEAR POLYNOMIAL FITTING RUN AND FOR A NON-LINEAR LEAST SQUARES ESTIMATION RUN.

METHOD:

THE VALUES OF TEMPERATURE, PRESSURE, AND DENSITY COEFFICIENTS RESIDE IN THE COMMON BLOCK COFCOM. FOR THE LINEAR POLYNOMIAL REPORT, ALL THE COEFFICIENTS ARE PRINTED OUT. FOR THE NON-LINEAR REPORT, ONLY THE TEMPERATURE COEFFICIENTS AND THE FIRST PRESSURE COEFFICIENT ARE PRINTED OUT.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
IA	I	I	FLAG FOR REPORT TYPE: =0, LINEAR POLYNOMIAL REPORT =1, NON-LINEAR REPORT

CALLING SUBROUTINE: POLADJ

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/COFCOM/	CT(3,4)	I	TEMPERATURE COEFFICIENTS
	CP(3,4)	I	PRESSURE COEFFICIENTS
	CD(3,4)	I	DENSITY COEFFICIENTS
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE

PROGRAMMER/ANALYST: A. K. KAPOOR, CSC MARCH 1981

Subroutine OUTSUM

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    SUBROUTINE PARAMS(IERR)

PURPOSE:
    PARAMS IS THE PARAMETER CALCULATION EXECUTIVE.

METHOD:
    1. CHECK TO SEE IF AN ENTREE OR A LAP TRAJECTORY IS
       TO BE PROCESSED.  CALL OUTPUT TO WRITE APPROPRIATE HEADERS.
    2. PRODUCE THE FIRST BLOCK OF TRAJECTORY POINTS BY CALLING
       ENTRD FOR AN ENTREE TRAJECTORY OR LAP FOR A LOCAL
       ATMOSPHERIC PROFILE.
    3. CALL MODELS TO RETURN TEMPERATURE, PRESSURE, DENSITY, AND
       WIND FOR EACH POINT IN THE BLOCK.
    4. CALL GASLAW TO CALCULATE PARAMETERS ASSOCIATED WITH THE
       IDEAL GAS LAW AND TO RECOMPUTE TEMPERATURE IN
       ACCORDANCE WITH THE GAS LAW.
    5. CALL PNCAL TO CALCULATE THE ONBOARD PRESSURE MEASUREMENT.
    6. CALL OUTPRF TO WRITE THE CALCULATED VALUES TO THE
       PRINTED REPORT AND TO THE USER OUTPUT FILE.
    7. CHECK TO SEE IF THE LAST POINT ON THE TRAJECTORY HAS
       BEEN PROCESSED.  IF NOT, RETRIEVE THE NEXT BLOCK OF POINTS
       AND REPEAT STEPS 3 THROUGH 6.
    8. RETURN.

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
    IERR       I       O      ERROR FLAG:
                               0=NO ERROR

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: LAP, ENTRD, MODELS, GASLAW, PNCAL, OUTPRF
```

Subroutine PARAMS (1 of 2)

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
/USECOM/	IPRFL	I	PROFILE TYPE =1, ENTREE =2, LAP
	IDBG	I	DEBUG FLAG
	Z1	I	LOWER LAP ALTITUDE
	Z2	I	UPPER LAP ALTITUDE
/CALCOM/	TRJ(5,10)	O	BLOCK OF TRAJECTORY POINTS Z, LAT,LONG,GMT,LST
	UTRJ(5,10)	O	TRAJECTORY POINT UNCERTAINTIES
	PRM(7,10)	O	BLOCK OF PARAMETERS CORRESPONDING TO EACH TRAJECTORY POINT: T, P, D, U, V, WS, WD
	UPRM(7,10)	O	UNCERTAINTIES IN PARAMETERS
	WTMOL(10)	O	MEAN MOLECULAR WEIGHTS
	SCHT(10)	O	PRESSURE SCALE HEIGHTS
	V(10)	I	SHUTTLE VELOCITIES (M/SEC)
	ALPHA(10)	I	SHUTTLE ANGLES OF ATTACK
	RMC(10)	O	CALCULATED MACH NUMBERS
	PNC(10)	O	CALCULATED ONBOARD PRESSURES
	DEV(10)	O	PERCENT DEVIATION FROM GAS LAW

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRNT	WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC, MARCH 1981

Subroutine PARAMS (2 of 2)

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    SUBROUTINE PHYSCS(Z,T,P,D,IERR)

PURPOSE:
    PHYSCS CALCULATES PRESSURE AND DENSITY FROM TEMPERATURE VIA
    PHYSICAL RELATIONSHIPS.

METHOD:
    1. CALL SIMP TO INTEGRATE THE INVERSE OF THE PRESSURE SCALE
       HEIGHT TO THE CURRENT ALTITUDE (SIMP IS A FORTRAN LIBRARY
       ROUTINE WHICH REQUIRES THE EXTERNAL ROUTINE PSCALE TO
       COMPUTE THE INVERSE SCALE HEIGHT).
    2. COMPUTE THE PRESSURE FROM THE INTEGRATED VALUE.
    3. COMPUTE THE DENSITY FROM THE PRESSURE.
    4. RETURN.

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
    Z          R       I      ALTITUDE (KM)
    T          R       I      TEMPERATURE AT Z (DEGREES K)
    P          R       O      PRESSURE AT Z (N/M**2)
    D          R       O      DENSITY AT Z (KG/M**3)
    IERR       I       O      ERROR FLAG
                               =0, NO ERROR

CALLING SUBROUTINES: POLY

SUBROUTINES CALLED: SIMP

COMMON BLOCK PARAMETERS USED:
  COMMON NAME    PARAMETER    I/O    DESCRIPTION
   /USECOM/        ZREF        I      REFERENCE ALTITUDE (KM) FOR
                                       INTEGRATION
                   PREF        I      PRESSURE AT ZREF
                   STEP        I      INTEGRATION STEPSIZE, KM
                   IDBG        I      DEBUG FLAG:
   /JRCOM/         CM          I      MEAN MOLECULAR MASS AT SEA LEVEL
                                       IN GM/MOLE
                   RC          I      UNIVERSAL GAS CONSTANT (MKS UNITS)
   /FILCOM/        NPRINT      I      PRINTED OUTPUT LUN

EXTERNAL DATA SETS USED:
       NAME            LUN          I/O OPERATIONS PERFORMED
       OUT             NPRINT       WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC
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Subroutine PHYSCS

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      SUBROUTINE PNCAL(V,ALPHA,TPDW,EPHSEC,POS,RM,PN)

PURPOSE:
      PNCAL CALCULATES THE ESTIMATED ONBOARD PRESSURE MEASUREMENT.

METHOD:
      1. CALCULATE THE SPEED OF SOUND AND MACH NUMBER.
      2. CALCULATE THE COEFFICIENT OF PRESSURE FOR THE SHUTTLE.
      3. CALCULATE THE DYNAMIC PRESSURE.
      4. CALCULATE THE ONBOARD PRESSURE MEASUREMENT.
      5. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    V         R      I     SHUTTLE VELOCITY (M/SEC)
    ALPHA     R      I     SHUTTLE ANGLE OF ATTACK (DEG)
    TPDW(7)   R      I     CALCULATED ATMOSPHERIC PARAMETERS AT
                            THIS TRAJECTORY POINT: T,P,D,U,V,
                            WS,WD (ONLY T,P,D -- THE FIRST THREE
                            WORDS OF THE ARRAY -- ARE USED)
    EPHSEC    R      I     SECONDS FROM EPOCH FOR THIS TRAJECTORY
                            POINT
    POS(4)    R      I     SHUTTLE TRAJECTORY POINT: ALT, LAT,
                            LOCAL SOLAR TIME, AND LONGITUDE
    RM        R      O     CALCULATED MACH NUMBER
    PN        R      O     CALCULATED ONBOARD PRESSURE MEASUREMENT

CALLING SUBROUTINE: PARAMS

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /FILCOM/      NPRINT      I     PRINTED OUTPUT LUN
   /USECOM/      IDBG        I     DEBUG FLAG
                 HMSSEC      I     EPOCH (GMT SECONDS)
   /JRCOM/       RC          I     GAS CONSTANT (MKS UNITS)
                 CM          I     MEAN MOLECULAR WEIGHT (G/MOLE)

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC,       MAY 1981
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Subroutine PNCAL

```
    SUBROUTINE POLADJ(IERR)

PURPOSE:
    POLADJ IS THE POLYNOMIAL MODEL ADJUSTMENT EXECUTIVE.

METHOD:
    1. IF ADJUSTED POLYNOMIAL MODEL IS REQUESTED, CALL METREF
       TO PRODUCE REFERENCE PROFILE.
    2. IF DEFAULT POLYNOMIAL MODEL IS REQUESTED, OR IF DEFAULT
       POINTS ARE TO BE ADDED TO REFERENCE METEOROLOGICAL
       PROFILE, CALL DFLINT.
    3. CALL POLFIT TO FIT THE POLYNOMIAL COEFFICIENTS TO THE
       REFERENCE PROFILE.
    4. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    IERR      I      O     ERROR FLAG:
                            =0, NO ERROR

CALLING SUBROUTINES: MODADJ

SUBROUTINES CALLED: METREF, DFLINT, POLFIT

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O     DESCRIPTION:
   /USECOM/       ILATL      I        INCLUDE LATITUDE VARIATIONS:
                                       =0, NO
                                       =1, YES
                  IDSDL      I        INCLUDE D/SD VARIATIONS:
                                       =0, NO
                                       =1, YES
                  IDBG       I        DEBUG FLAG
                  IDFLPT     I        INCLUDE DEFAULT POINTS:
                                       =0, NO
                                       =1, YES
                  IDC        I        DC FLAG
                  BOUND      I        3 SEGMENT BOUNDARIES (KM)
                  RMERGE     I        REGION FOR MERGING
   /FILCOM/       NPRINT     I        PRINTED OUTPUT LUN
   /INTCOM/       IPTFLG     O        FLAG TO REINITIALIZE DFLINT

EXTERNAL DATA SETS USED:
      NAME          LUN       I/O OPERATIONS PERFORMED
      OUT          NPRINT      WRITE(DEBUG ONLY)
      WRK          NWRK        REWIND

PROGRAMMER: D.E. BOLAND, CSC
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Subroutine POLADJ

SUBROUTINE POLCAL(Z,T,P,D,IERR)

PURPOSE:

POLCAL CALCULATES THE TEMPERATURE, PRESSURE, AND DENSITY FROM THE POLYNOMIAL COEFFICIENTS.

METHOD:

1. COMPUTE TEMPERATURE, PRESSURE, AND DENSITY FROM THE POLYNOMIAL COEFFICIENTS FOR THIS ALTITUDE (COMPUTE TEMPERATURE ONLY IF THE 'DERIVE' OR 'DC' OPTIONS HAVE BEEN SELECTED.
2. RETURN.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
Z	R	I	ALTITUDE (KM)
T	R	I	TEMPERATURE AT Z (DEGREES K)
P	R	O	PRESSURE AT Z (N/M**2)
D	R	O	DENSITY AT Z (KG/M**3)
IERR	I	O	ERROR FLAG =0, NO ERROR

CALLING SUBROUTINES: POLY, PSCALE

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	IDBG	I	DEBUG FLAG
	ISEG	I	ATMOSPHERIC SEGMENT NUMBER
	BOUND(3)	I	3 SEGMENT BOUNDARIES: DEFAULT=90 KM, 65 KM, 25 KM
	RMERGE	I	REGION FOR MERGING ON EACH SIDE OF EACH SEGMENT BOUNDARY: DEFAULT = 5 KM
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
/COFCOM/	CT	I	4 TEMPERATURE COEFFICIENTS FOR EACH SEGMENT
	CP	I	4 PRESSURE COEFFICIENTS FOR EACH SEGMENT
	CD	I	4 DENSITY COEFFICIENTS FOR EACH SEGMENT

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC

Subroutine POLCAL

SUBROUTINE POLERR(DZ,T,P,D,ISEG,UT,UP,IERR)

PURPOSE:
POLERR ESTIMATES THE ERRORS (UNCERTAINTIES) ASSOCIATED WITH THE POLYNOMIAL CALCULATION OF TEMPERATURE, PRESSURE, AND DENSITY.

METHOD:

1. SKIP THE NON-DC CALCULATION SINCE THE COVARINACE MATRIX IS UNAVAILABLE FROM THE LIBRARY ROUTINE LSQPOL.
2. FOR A DC RUN, CALL DCERR TO CALCULATE THE SQUARE ROOT OF THE VARIANCE AT ALTITUDE DZ FOR EACH PARAMETER.
3. RETURN.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
DZ	R	I	ALTITUDE (SEGMENT BOUNDARY - Z , KM)
T	R	I	TEMPERATURE, DEGREES KELVIN
P	R	I	PRESSURE, N/M**2
D	R	I	DENSITY, KG/M**3
UT	R	O	TEMPERATURE UNCERTAINTY
UP	R	O	PRESSURE UNCERTAINTY
UD	R	O	DENSITY UNCERTAINTY
IERR	I	O	ERROR FLAG

CALLING SUBROUTINE: POLY

SUBROUTINES CALLED: LINERR, DCERR

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/COFCOM/	COVAT	I	TEMPERATURE COVARIANCE MATRIX
	COVAP	I	PRESSURE COVARIANCE MATRIX
	COVAD	I	DENSITY COVARIANCE MATRIX
	BOUND	I	POLYNOMIAL SEGMENT BOUNDARIES
/USECOM/	IDC	I	DC FLAG

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC AUGUST 1981

Subroutine POLERR

SUBROUTINE POLFIT(ISEG,NMET,Z,T,P,D,WT,WP,WD,IERR)

PURPOSE:

POLFIT CONTROLS THE FITTING OF POLYNOMIAL COEFFICIENTS.

METHOD:

1. IF THIS NOT A DC RUN, CALL LSQPOL 3 TIMES TO PERFORM LINEAR LEAST-SQUARES FITTING OF THE TEMPERATURE, PRESSURE, AND DENSITY COEFFICIENTS. CALL OUTRES TO OUTPUT THE RESIDUAL REPORTS.
2. IF THIS IS A DC RUN, CALL NLSPOL TO ADJUST THE TEMPERATURE COEFFICIENTS VIA THE NONLINEAR LEAST SQUARES PROCESS. CALL OUTRES TO OUTPUT THE RESIDUAL REPORTS.
3. RETURN.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
ISEG	I	I	ATMOSPHERIC SEGMENT NUMBER
NMET	I	I	NUMBER OF POINTS IN THIS SEGMENT
Z	R	I	ALTITUDE ARRAY
T	R	I	TEMPERATURE ARRAY
P	R	I	PRESSURE ARRAY
D	R	I	DENSITY ARRAY
WT	R	I	TEMPERATURE WEIGHTS
WP	R	I	PRESSURE WEIGHTS
WD	R	I	DENSITY WEIGHTS
IERR	I	O	ERROR FLAG

CALLING SUBROUTINE: POLADJ

SUBROUTINES CALLED: LSQPOL, NLSPOL, OUTRES, XALFA, VCMTRX

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/COFCOM/	CT	O	4 TEMPERATURE COEFFICIENTS FOR EACH SEGMENT
	CP	O	4 PRESSURE COEFFICIENTS FOR EACH SEGMENT
	CD	O	4 DENSITY COEFFICIENTS FOR EACH SEGMENT
	UT	O	TEMPERATURE STANDARD DEVIATION FOR EACH SEGMENT
	UP	O	PRESSURE STANDARD DEVIATION FOR EACH SEGMENT
	UD	O	DENSITY STANDARD DEVIATION FOR EACH SEGMENT
	COVAT	O	TEMPERATURE COVARIANCE MATRIX FOR EACH SEGMENT

Subroutine POLFIT (1 of 2)

/USECOM/	IDBG	I	DEBUG FLAG
	IDC	I	DC FLAG
	ITDAT	I	DC TEMPERATURE SELECTION FLAG
	IPDAT	I	DC PRESSURE SELECTION FLAG
	IDDAT	I	DC DENSITY SELECTION FLAG
	KWRITE	I	OUTPUT SUPPRESSION FLAG
	BOUND	I	SEGMENT BOUNDARIES
	ZREF	I	REFERENCE ALTITUDE FOR INTEGRATION
	PREF	I	PRESSURE AT ZREF
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
/JRCOM/	TJREF	I	TEMPERATURE AT TOP BOUNDARY
	RC	I	GAS CONSTANT (MKS UNITS)
	RMAV	I	MEAN MOLECULAR WEIGHT (CGS UNITS)
	DJREF	I	DENSITY AT TOP BOUNDARY
/DCCOM/	MLDATA	I	DATA SELECTION FLAGS
	KSSEG	I	CONTINUITY FLAG
	ISGM	I	SEGMENTATION FLAG
	IDCSEG	I	DC FLAG FOR EACH SEGMENT
	ALFA	I/O	INTEGRANDS FOR P AND D

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC

Subroutine POLFIT (2 of 2)

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    SUBROUTINE POLY(POS,TPDW,UTPDW,IERR)

PURPOSE:
    POLY CONTROLS THE CALCULATION OF ATMOSPHERIC PARAMETERS
    VIA THE POLYNOMIAL MODEL.

METHOD:
    1. DETERMINE WHICH POLYNOMIAL SEGMENT THIS POINT IS IN.
    2. CALL POLCAL OR PHYSCS TO CALCULATE TEMPERATURE, PRESSURE,
       AND DENSITY.
    3. CALL DFLINT TO READ VALUES OF TRANSLATIONAL COEFFICIENTS
       FROM WORKING FILE.  CALL TRNLAT AND TRNDSD TO TRANSLATE
       PARAMETERS IN LATITUDE AND LOCAL SOLAR TIME.
    4. CALCULATE UNCERTAINTIES
    5. RETURN.

ARGUMENT LIST:
   ARGUMENT   TYPE   I/O   DESCRIPTION
     POS        R      I     TRAJECTORY POINT:
                              POS(1)=ALTITUDE
                              POS(2)=LATITUDE
                              POS(3)=LOCAL SOLAR TIME
                              POS(4)=LONGITUDE
     TPDW       R      O     CALCULATED ATMOSPHERIC PARAMETERS:
                              TPDW(1)=TEMPERATURE
                              TPDW(2)=PRESSURE
                              TPDW(3)=DENSITY
                              TPDW(4)=E-W WIND U
                              TPDW(5)=N-S WIND V
                              TPDW(6)=WIND SPEED WS
                              TPDW(7)=WIND DIRECTION WD
     UTPDW      R      O     UNCERTAINTIES IN PARAMETERS (7)
     IERR       I      O     ERROR FLAG:
                              =0, NO ERROR

CALLING SUBROUTINE: MODELS

SUBROUTINES CALLED: POLCAL, PHYSCS, DFLINT, TRNLAT, TRNDSD, POLERR
```

Subroutine POLY (1 of 2)

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	ILATL	I	INCLUDE LATITUDE VARIATIONS: =0, NO =1, YES
	IDSDL	I	INCLUDE D/SD VARIATIONS: =0, NO =1,YES
	IDRV	I	DERIVE P AND D FROM T: =0, NO =1, YES
	IDBG	I	DEBUG FLAG
	ISEG	O	ATMOSPHERIC SEGMENT NUMBER
	BOUND(3)	I	3 SEGMENT BOUNDARIES: DEFAULT=90 KM, 65 KM, 25 KM
	RMERGE	I	REGION FOR MERGING ON EACH SIDE OF EACH SEGMENT BOUNDARY: DEFAULT = 5 KM
	REFLAT	I	MODEL REFERENCE LATITUDE
	REFTAU	I	MODEL REFERENCE LOCAL SOLAR TIME
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
/COFCOM/	CP	I	PRESSURE COEFFICIENTS ARRAY
	RMST(3)	I	TEMPERATURE RMS FOR EACH SEGMENT
	RMSP(3)	I	PRESSURE RMS FOR EACH SEGMENT
	RMSD(3)	I	DENSITY RMS FOR EACH SEGMENT

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE (DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC

Subroutine POLY (2 of 2)

SUBROUTINE PPAR(RINT,DPDS)

PURPOSE:
PPAR COMPUTES PARTIAL DERIVATIVES OF PRESSURE WITH RESPECT TO SOLVE-FOR PARAMETERS

METHOD:
USING PREVIOUSLY COMPUTED INTEGRALS AND CURRENT SOLVE-FOR PARAMETERS, COMPUTES PARTIAL DERIVATIVES OF LOG PRESSURE WITH RESPECT TO TEMPERATURE COEFFIENTS AND LOG BOUNDARY PRESSURE

CALLING SUBROUTINE: NLSPOL

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/SOLAND/	IMAX	I	MAX. NUMBER OF INTEGRALS
	KSOLA4	I	=0 DOES NOT SOLVE FOR BOUNDARY TEMP. =1 SOLVES FOR BOUNDARY TEMP.
	NPOL	I	ORDER OF TEMP. POLYNOMIAL
	A	I	SOLVE-FOR PARAMETER ARRAY

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC   MARCH 1981

Subroutine PPAR

```
    SUBROUTINE PSCALE(Z,HPI)

PURPOSE:
    PSCALE COMPUTES THE INVERSE OF THE PRESSURE SCALE HEIGHT.

METHOD:
    1. COMPUTE THE ACCELERATION OF GRAVITY AT THIS ALTITUDE.
    2. COMPUTE THE INVERSE OF THE SCALE HEIGHT.
    3. RETURN.

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O   DESCRIPTION
    Z          R       I     ALTITUDE (KM)
    HPI        R       O     INVERSE PRESSURE SCALE HEIGHT (KM**-1)

CALLING SUBROUTINES: SIMP

SUBROUTINES CALLED: POLCAL

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /JRCOM/        GLO        I     SEA LEVEL VALUE OF G (M/SEC**2)
                  RAV        I     AVERAGE EARTH RADIUS (KM)
                  CM         I     MEAN MOLECULAR MASS AT SEA
                                    LEVEL (GM/MOLE)
                  TZ         I     TEMPERATURE AT ALTITUDE Z (KELVIN)
                  RC         I     UNIVERSAL GAS CONSTANT (MKS UNITS)

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC
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Subroutine PSCALE

SUBROUTINE READIN(NFIN,IERR)

PURPOSE:
READIN READS THE KEYWORD CARD DECK AND, IF REQUIRED, THE ENTREE FILE HEADER, AND STORES THE INPUT PARAMETERS IN COMMON.

METHOD:
1. WRITE THE TITLE FOR THE KEYWORD CARD IMAGES.
2. READ A CARD AND WRITE ITS IMAGE.
3. BRANCH TO THE APPROPRIATE SECTION OF CODE TO SET THE COMMON BLOCK PARAMETERS INPUT ON THIS CARD. IF THIS AN ENTREE PROFILE RUN, READ THE HEADER ON THE ENTREE FILE ALSO.
4. REPEAT STEPS 2 AND 3 UNTIL THE 'END' CARD IS READ.
5. RETURN.

ARGUMENT LIST

ARGUMENT	TYPE	I/O	DESCRIPTION
NFIN	I	O	FLAG TO END STACKED DECK PROCESSING: =1, LAST DECK
IERR	I	O	ERROR FLAG: =0, NO ERROR

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: HMSCON

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	IPRFL	O	TYPE OF PROFILE
	MODL	O	TYPE OF LOWER ATMOSPHERIC MODEL
	IWL	O	TYPE OF L.A. WIND MODEL
	ILATL	O	LATITUDE VARIATIONS IN L.A.
	IDSDL	O	DIURNAL/SEMIDIURNAL VARIATIONS, L.A.
	MODU	O	TYPE OF UPPER ATMOSPHERIC MODEL
	IWU	O	TYPE OF U.A. WIND MODEL
	ILATU	O	LATITUDE VARIATIONS IN U.A.
	IDSDU	O	DIURNAL/SEMIDIURNAL VARIATIONS, U.A.
	IDRV	O	DERIVE PRESSURE AND DENSITY FROM TEMPERATURE VIA PHYSICAL LAWS (OVERRIDES ALL OTHER SELECTIONS)
	INTP	O	INTERPOLATOR TYPE
	IDBG	O	PRINT DEBUG
	INTPB	O	BIVARIATE INTERPOLATOR TYPE
	IDNUM	O	ENTREE-LAP ID NUMBER
	IGAS	O	GAS LAW CALCULATION OVERRIDE
	NSAMP	O	ENTREE FILE SAMPLING INTERVAL (EACH NSAMPTH POINT READ)
	ITER	O	MAXIMUM NUMBER OF DC ITERATIONS
	IWT	O	WEIGHTING FLAG
	IDSDA	O	D/SD COEFFICIENT ADJUSTMENT
	ILATA	O	LATITUDE GRADIENT ADJUSTMENT
	IDC	O	DC FLAG
	ITDAT	O	SOURCE OF T OBSERVATIONS FOR DC
	IPDAT	O	SOURCE OF P OBSERVATIONS FOR DC

Subroutine READIN (1 of 2)

	IDDAT	O	SOURCE OF D OBSERVATIONS FOR DC
	IDMY	O	DUMMY
	NFIL	O	NUMBER OF MET FILES
	KWRITE	O	OUTPUT SUPPRESSION FLAG
	YMD	O	YEAR, MONTH, DAY OF LAP OR ENTREE TRAJECTORY
	HMS	O	HOURS, MINUTES, SECONDS OF FIRST POINT ON ENTREE TRAJECTORY
	THETA	O	LATITUDE OF LAP
	TAU	O	LONGITUDE OF LAP
	Z1	O	LOWER LAP ALTITUDE
	Z2	O	UPPER LAP ALTITUDE
	DZ	O	LAP ALTITUDE INTERVAL
	BOUND	O	BOUNDARY BETWEEN SEGMENTS
	HMSSEC	O	ENTREE FILE HMS START TIME IN DECIMAL SECONDS
	ZREF	O	REFERENCE ALTITUDE (KM)
	PREF	O	PRESSURE AT ZREF (N/M2)
	STEP	O	STEPSIZE
	CONV	O	CONVERGENCE CRITERION FOR DC
	RMERGE	O	REGION FOR SEGMENT MERGING
	REFLAT	O	REFERENCE LATITUDE
	REFTAU	O	REFERENCE LOCAL SOLAR TIME
	RMGMT	O	GMT OF MET FILES
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
	NREAD	I	CARD INPUT LUN
	NENT	I	ENTREE FILE LUN
/DCCOM/	MLDATA	O	DC DATA SELECTION FLAGS
	KSSEG	O	DC CONTINUITY FLAGS
	ISGM	O	DC SEGMENTATION FLAG
	ISEGDC	O	DC INCLUSON FLAG FOR SEGMENT
	WTDCT	O	WEIGHTING FOR TEMPERATURE
	WTDCP	O	WEIGHTING FOR PRESSURE
	WTDCD	O	WEIGHTING FOR DENSITY

EXTERNAL DATA SETS USED

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE
CARDS	NREAD	READ
ENT	NENT	READ

PROGRAMMER: D. E. BOLAND, CSC, MARCH 1981

Subroutine READIN (2 of 2)

```
    FUNCTION RLST(LONG,SECHMS,EPHSEC)

PURPOSE:
    RLST CONVERTS LONGITUDE AND GMT(IN SECONDS) INTO LOCAL SOLAR
    TIME(SOLAR HOUR ANGLE).

METHOD:
    1. CONVERT LONGITUDE(DEGREES) TO SECONDS OF TIME EAST OF
    GREENWICH.
    2. ADD GMT IN SECONDS TO TIME EAST OF GREENWICH TO PRODUCE
    LOCAL SOLAR TIME IN SECONDS.
    3. CONVERT LST IN SECONDS TO LST IN HOURS.

ARGUMENT LIST:
  ARGUMENT    TYPE   I/O   DESCRIPTION
    LONG        R     I     LONGITUDE EAST OF GREENWICH (DEGREES)
    SECHMS      R     I     EPOCH HMS CONVERTED TO SECONDS
    EPHSEC      R     I     SECONDS FORM EPOCH (DECIMAL SEC. OF TIME)
    RLST        R     O     LOCAL SOLAR TIME (DECIMAL HOURS)

CALLING SUBROUTINES: PARAMS

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: R.A. KUSESKI, CSC
```

Function RLST

```
  SUBROUTINE ROOTS(A,NA,CROOTS,IRL)

PURPOSE:
 THIS SUBROUTINE COMPUTES ANY DESIRED COMPLEX ROOTS (ZEROES) OF A
 GIVEN POLYNOMIAL, IF APPROXIMATIONS TO THE DESIRED ROOTS ARE KNOWN.

METHOD:
 NEWTON'S METHOD, AS DESCRIBED IN THE REFERENCE.

REFERENCE:
 HENRICI, P., 'ELEMENTS OF NUMERICAL ANALYSIS', NEW YORK, WILEY,
 1965, PAGE 84.

CALLING SEQUENCE:
   CALL ROOTS (A,NA,CROOTS,IRL)
   WHERE:
 A      IS AN INPUT DIMENSION NA ARRAY OF REAL (NONIMMAGINARY) POLY-
        NOMIAL COEFFICIENTS, STARTING WITH THE LOWEST POWER.
 NA     IS THE NUMBER OF IMPUT COEFFICIENTS (ONE MORE THAN THE
        DEGREE OF THE POLYNOMIAL).
 CROOTS IS A COMPLEX*16 ARRAY OF DIMENSION NA CONTAINING THE
        STARTING APPROXIMATIONS TO THE DESIRED ROOTS ON INPUT AND THE
        SOLUTIONS ON OUTPUT.
 IRL    IS THE NUMBER OF ROOTS (ZEROES) DESIRED TO BE SOLVED FOR.

COMMON BLOCK PARAMETERS:
 NONE

SUBROUTINES CALLED:
 NONE

CALLED BY:
 LOWALT

PROGRAMMER:
 J. P. MOLINEAUX, COMPUTER SCIENCES CORPORATION.
```

Subroutine ROOTS

SUBROUTINE SETREF(IERR)

PURPOSE:

SETREF SETS THE REFERENCE VALUES AT THE TOP SEGMENT BOUNDARY AND AT ZREF FOR THE JR MODEL, THE DC PROCESS, AND THE DERIVATION OF P AND D FROM T BY INTEGRATION.

METHOD:

1. WRITE REPORT HEADER.
2. IF METEOROLOGICAL FILES ARE BEING USED, READ HEADERS AND CALL METINT TO INTERPOLATE THE NEEDED VALUES. IF DEFAULT MODELS ARE BEING USED, CALL DFLINT TO INTERPOLATE NEEDED VALUES FROM THE DEFAULT FILES.
3. REPORT THESE VALUES AND HEADER INFORMATION.
4. RETURN.

ARGUMENT LIST:

ARRGUMENT	TYPE	I/O	DESCRIPTION
IERR	I	O	ERROR FLAG

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: METINT, DFLINT

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	MODL	I	TYPE OF LOWER ATMOSPHERIC MODEL
	IDRV	I	FLAG FOR P AND D DERIVATION
	NFIL	I	NO. OF METEOROLOGICAL FILES
	BOUND(3)	I	ATMOSPHERIC SEGMENT BOUNDARIES
	ZREF	I	INTEGRATION REFERENCE HEIGHT
	PREF	O	PRESSURE AT ZREF
	REFLAT	I	MODEL REFERENCE LATITUDE
	REFTAU	I	MODEL REFERENCE LOCAL SOLAR TIME
/JRCOM/	ZBND	O	TOP SEGMENT BOUNDARY
	TBND	O	TEMPERATURE AT ZBND
	DBND	O	DENSITY AT ZBND
/FILCOM/	NPRINT	I	PRINTED OUTPUT LUN
	NWRK	I	DEFAULT WORKING FILE LUN
	MWF(3)	I	METEOROLOGICAL FILES LUNS
/INTCOM/	I2	O	INTERPOLATION INITIALIZATION FLAG
/METCOM/	MI2	O	INTERPOLATION INITIALIZATION FLAG

EXTERNAL DATA SETS USED:

NAME	LUN	I/O OPERATIONS PERFORMED
OUT	NPRINT	WRITE
WRK	NWRK	READ, REWIND
MET(3)	MWF(3)	READ, REWIND

PROGRAMMER: D. E. BOLAND, CSC, MARCH 1981

Subroutine SETREF

SUBROUTINE SOLVE(KSOL,KDPMET,DELTAS,VCMAT,IERR)

PURPOSE:
SOLVE SOLVES THE NORMAL EQUATION BY INVERTING THE NORMAL MATRIX.

METHOD:
USE THE SUBROUTINE SYMINV TO INVERT THE NORMAL MATRIX.

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
KSOL	I	I	=1 SOLVES FOR ALL FIVE PARAMETERS
			=2 SOLVES FOR THREE TEMP. COEFFS
			=3 SOLVES FOR ALL TEMP. COEFFS
			=4 SOLVES FOR THREE TEMP. AND ONE PRESS. COEFFS
KDPMET	I	I	=0 NO PRES. OR DEN. DATA USED
			=1 PRES. OR DEN. OR BOTH TYPES OF DATA USED
DELTAS	R	O	CORRECTION SOLVE-FOR VECTOR
VCMAT	R	O	VARIANCE-COVARIANCE MATRIX
IERR	I	O	ERROR FLAG

CALLING SUBROUTINES: NLSPOL

SUBROUTINES CALLED: SYMINV

COMMON BLOCK PARAMETERS USED:

COMMON NAME	PARAMETER	I/O	DESCRIPTION
/USECOM/	KPRNT	I	UNIT NUMBER FOR PRINTING
/SOLAND/	KSOLA4	I	=0 DOES NOT SOLVE FOR TEMP. BOUND. VALUE
			=1 SOLVES FOR TEMP. BOUND.VALUE
	KSOLA5	I	=0 DOES NOT SOLVE FOR PRES. BOUND. VALUE
			=1 SOLVES FOR PRES. BOUND. VALUE
	NPOL	I	ORDER OF POLYNOMIALS FOR TEMP.
	MAXSOL	I	MAX. NUMBER OF SOLVE-FOR PARAMETERS
	NSOLV	I	NUMBER OF SOLVE-FOR PARAMETERS
	KEDTOT	I	TOTAL NUMBER OF MET. DATA INCLUDED
	KONVRG	O	CONVERGENCE FLAG
			=1 CONVERGED
			=2 CONVERGING
			=3 DIVERGING
			=4 CONVERGED: LINEAR FITTING
	EPSLON	I	CONVERGENCE CRITERIA
	SRSUM	I	TOTAL SUM OF SQUARED WEIGHTED RESIDUALS
	CURRMS	O	CURRENT WEIGHTED RMS
	OLDRMS	O	PREVIOUS WEIGHTED RMS
	RMSP	O	PREDICTED WEIGHTED RMS
	A	I/O	SOLVE-FOR PARAMETER ARRAY
	G	I	RIGHT-HAND SIDE OF NORMAL EQUATION
	SH	I	LINEAR ARRAY OF NORMAL MATRIX

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC MARCH 1981

Subroutine SOLVE

```
    SUBROUTINE SYMINV(SUM1,NDIM,NLIM,DELTA,IERR)

PURPOSE:
    SYMINV INVERTS A SYMMETRIC COEFFICIENT MATRIX, REQUIRING ONLY
    THE UPPER TRIANGULAR PORTION OF THE MATRIX.

METHOD:
    1. RECURSIVELY FIND THE INVERSE OF N X N MATRIX KNOWING THE
       INVERSE OF (N-1) X (N-1) MATRIX UNTIL THE INVERSE OF AN
       NLIM X NLIM SQUARE PARTITION MATRIX IS FOUND (SCHUR
       IDENTITY METHOD OF PARTITIONING).
    2. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    SUM1       R    I/O    I: UPPER TRIANGULAR FORM OF SYMMETRIC
                              MATRIX STORED BY ROW
                           O: UPPER TRIANGULAR FORM OF SYMMETRIC
                              MATRIX WITH SUBMATRIX INVERTED
    NDIM       I     I     DIMENSION OF MATRIX 'SUM1'
    NLIM       I     I     DIMENSION OF SUBMATRIX TO BE INVERTED
    DELTA      R     I     WORKING ARRAY
    IERR       I     O     ERROR FLAG

CALLING SUBROUTINE: SOLVE

SUBROUTINES CALLED: COVUP

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: DOLORES P. MORGAN, GSFC, NASA (FOR GTDS)
            MODIFIED FOR USE IN LAIRS BY D. E. BOLAND, CSC
```

Subroutine SYMINV

```
    SUBROUTINE TPAR(ZR,DTDS)

PURPOSE:
    TPAR COMPUTES PARTIAL DERIVATIVES OF TEMPERATURE WITH RESPECT TO
    SOLVE-FOR PARAMETERS

METHOD:
    USING THE POLYNOMIAL EXPRESSION OF TEMPERATURE, COMPUTE PARTIAL
    DERIVATIVES WITH RESPECT TO THE TEMPERATURE COEFFIENTS

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O     DESCRIPTION
    ZR        R      I      ALTITUDE WITH RESPECT TO THE REFERENCE
                            ALTITUDE
    DTDS      R      O      COMPUTED PARTIAL DERIVATIVE ARRAY

CALLING SUBROUTINE: NLSPOL

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
   COMMON NAME PARAMETER  I/O   DESCRIPTION
   /SOLAND/       NPOL     I    ORDER OF TEMP. POLYNOMIAL
                  KSOLA4   I    =0 DOES NOT SOLVE FOR BOUNDARY TEMP.
                                =1 SOLVES FOR BOUNDARY TEMP.

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC       MARCH 1981
```

Subroutine TPAR

```
SUBROUTINE TRNADJ(IERR)

PURPOSE:
    TRNADJ CONTROLS THE ADJUSTMENT OF LATITUDE GRADIENTS AND
    DIURNAL/SEMIDIURNAL COEFFICIENTS.

METHOD:
    1. RETRIEVE DEFAULT COEFFICIENTS FROM WORK AREA /SCRATCH/.
    2. INTERPOLATE T, P, AND D FROM THE METEOROLOGICAL FILES
       AT EACH ALTITUDE REPRESENTED BY THE DEFAULT COEFFICIENTS.
    3. CALCULATE THE NEW LATITUDE GRADIENTS
    4. CALCULATE THE NEW DIURNAL/SEMIDIURNAL COEFFICIENTS.
    5. WRITE THE NEW COEFFICIENTS TO THE WORK AREA SCRATCH.
    6. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    IERR      I      O     ERROR FLAG

CALLING SUBROUTINE: WFILE

SUBROUTINES CALLED: METIN1,RLST,LATADJ,DSDADJ

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/      NFIL        I     NO. OF METEOROLOGICAL FILES
                 RGMT(3)     I     TIMES OF MET. FILES (GMT)
                 ILATA       I     FLAG FOR LAT. GRAD. ADJUSTMENT
                 IDSDA       I     FLAG FOR D/SD COEF. ADJUSTMENT
   /FILCOM/      NPRINT      I     PRINTED OUTPUT LUN
                 NWRK        I     WORKING FILE LUN
                 MWF(3)      I     MET. FILES LUNS
   /SCRATCH/     TAD(23,38)  I     CONTENTS OF WORKING FILE
                                   (WORK AREA)
   /INTCOM/      I2          I     FLAG TO REINITIALIZE DFLINT
   /METCOM/      MI2         I     FLAG TO REINITIALIZE METINT

EXTERNAL DATA SETS USED:
    NAME          LUN        I/O OPERATIONS PERFORMED
    OUT           NPRINT      WRITE (DEBUG ONLY)
    MWF           MWF(3)      REWIND

PROGRAMMER: D. E. BOLAND, CSC,      MARCH 1981
```

Subroutine TRNADJ

```
      FUNCTION TRNDSD(F,DAF,DPF,SDAF,SDPF,TAU,REFTAU)

PURPOSE:
      TRNDSD TRANSLATES THE PARAMETER F FROM A REFERENCE SOLAR
      TIME TO LOCAL SOLAR TIME.

METHOD:
      EXTRAPOLATE F IN TIME WITH THE DIURNAL AND SEMIDIURNAL
      COEFFICIENTS OF F (PHASE IS LOCAL SOLAR TIME OF MAXIMUM).

      ARGUMENT LIST:
ARGUMENT    TYPE    I/O    DESCRIPTION
      F         R       I      PARAMETER TO BE TRANSLATED
      DAF       R       I      DIURNAL AMPLITUDE OF F
      DPF       R       I      DIURNAL PHASE OF F
      SDAF      R       I      SEMIDIURNAL AMPLITUDE OF F
      SDPF      R       I      SEMIDIURNAL PHASE OF F
      TAU       R       I      LOCAL SOLAR TIME
      REFTAU    R       I      REFERENCE SOLAR TIME
      TRNDSD    R       O      TRANSLATED VALUE OF F

CALLING SUBROUTINES: DFLINT,METINT,LOWATM

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
   COMMON NAME    PARAMETER    I/O    DESCRIPTION
     /CONCOM/        TWOPI        I      TWO TIMES PI

EXTERNAL DATA SETS USED:

PROGRAMMER: D. E. BOLAND, CSC
```

Function TRNDSD

```
    FUNCTION TRNLAT(F,DF,RLAT,REFLAT)

PURPOSE:
    TRNLAT TRANSLATES THE PARAMETER F FROM A REFERENCE LATITUDE
    TO ANOTHER LATITUDE

METHOD:
    EXTRAPOLATE F IN LATITUDE WITH THE LATITUDE GRADIENT OF F

ARGUMENT LIST
  ARGUMENT    TYPE    I/O    DESCRIPTION
    F          R       I     PARAMETER TO BE TRANSLATED
    DF         R       I      LATITUDE GRADIENT OF F
    RLAT       R       I      LATITUDE TO WHICH F IS TO BE TRANSLATED
    REFLAT     R       I      REFERENCE LATITUDE
    TRNLAT     R       O      TRANSLATED VALUE OF F

CALLING SUBROUTINES: DFLINT,METINT,LOWATM

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC
```

Function TRNLAT

```
      SUBROUTINE VCMTRX(ISEGM,BOUND,PBOUND,ALFA,COVAT,IERR)

PURPOSE:
      VCMTRX COMPUTES THE CONTRIBUTION TO THE 5 X 5 VARIANCE-
      COVARIANCE MATRIX FROM THE FIXED BOUNDARY TEMPERATURE
      AND PRESSURE.

METHOD:
      1. COMPUTE A 2 X 2 VARIANCE-COVARIANCE MATRIX FOR FIXED
         BOUNDARY TEMPERATURE AND PRESSURE USING THE VARIANCE-
         COVARIANCE MATRIX OF THE PREVIOUS SEGMENT.
      2. CONSTRUCT A DIRECT SUM OF THE 3 X 3 VARIANCE-COVARIANCE
         MATRIX OF THE CURRENT SEGMENT AND THE 2 X 2 MATRIX
         COMPUTED IN STEP 1.

ARGUMENT LIST:
   ARGUMENT    TYPE    I/O    DESCRIPTION
     ISEGM       I      I      SEGMENT NUMBER
     BOUND       R      I      SEGMENT BOUNDARIES
     PBOUND      R      I      PRESSURE AT UPPER BOUNDARY
     ALFA        R      I      INTEGRALS NEEDED FOR COMPUTING
                                PARTIAL DERIVATIVES
     COVAT       R     I/O     VARIANCE-COVARIANCE MATRIX
     IERR        I      O      ERROR FLAG

CALLING SUBROUTINES: POLFIT

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC,        SEPTEMBER 1981
```

Subroutine VCMTRX

```
    SUBROUTINE WCNVRT(U,V,WS,WD,UU,UV,UWS,UWD)

PURPOSE:
    WCNVRT CONVERTS WIND COMPONENTS U AND V TO WIND SPEED WS AND
    WIND DIRECTION WD. IT ALSO CONVERTS THE UNCERTAINTIES.

METHOD:
    1. PERFORM COMPONENTS CONVERSION.
    2. PERFORM UNCERTAINTIES CONVERSION.
    3. RETURN.

ARGUMENT LIST:
  ARGUMENT   TYPE   I/O   DESCRIPTION
    U          R     I     EAST-WEST WIND COMPONENT (M/SEC)
    V          R     I     NORTH-SOUTH WIND COMPONENT (M/SEC)
    WS         R     O     WIND SPEED (M/SEC)
    WD         R     O     WIND DIRECTION (DEGREES)
    UU         R     I     E-W WIND UNCERTAINTY (M/SEC)
    UV         R     I     N-S WIND UNCERTAINTY (M/SEC)
    UWS        R     O     WIND SPEED UNCERTAINTY (M/SEC)
    UWD        R     O     WIND DIRECTION UNCERTAINTY (M/SEC)

CALLING SUBROUTINES: MODELS

SUBROUTINES CALLED: NONE

COMMON BLOCK PARAMETERS USED:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
    /CONCOM/      RTD        I     RADIANS TO DEGREES CONVERSION
                                   FACTOR
                  DTR        I     DEGREES TO RADIANS CONVERSION
                                   FACTOR

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: D. E. BOLAND, CSC
```

Subroutine WCNVRT

```
    SUBROUTINE WFILE(IERR)

PURPOSE:
    WFILE BUILDS THE WORKING FILE FROM THE PERMANENT FILE.

METHOD:
     1. LOCATE THE PROPER MONTH ON THE PERMANENT FILE.
     2. READ THE PROFILE FOR THAT MONTH.
     3. REVERSE THE ALTITUDE ORDERING OF THE PROFILE AND WRITE IT
        TO THE WORKING FILE.
     4. ADJUST LATITUDE GRADIENTS AND DIURNAL/SEMIDIURNAL
        COEFFICIENTS IF REQUIRED.
     5. RETURN.

ARGUMENT LIST:
   ARGUMENT    TYPE    I/O   DESCRIPTION
      IERR      I       O     ERROR FLAG:
                              =0, NO ERROR

CALLING SUBROUTINE: LAIRS

SUBROUTINES CALLED: TRNADJ

COMMON BLOCK PARAMETERS USED:
  COMMON NAME    PARAMETER    I/O    DESCRIPTION
   /USECOM/        IDBG         I      DEBUG FLAG
                   RYMD         I      YEAR,MONTH,DAY OF ENTREE
                                       TRAJECTORY OR LAP
                   ILATA        I      FLAG FOR LAT. GRAD. ADJUSTMENT
                   IDSDA        I      FLAG FOR D/SD COEF. ADJUSTMENT
   /FILCOM/        NPRINT       I      PRINTED OUTPUT LUN
                   NPRM         I      PERMANENT FILE LUN
                   NWRK         I      WORKING FILE LUN
   /SCRATCH/       TAD(23,38)   I      WORKING FILE CONTENTS
                                       (WORK AREA)

EXTERNAL DATA SETS USED:
       NAME         LUN          I/O OPERATIONS PERFORMED
       OUT          NPRINT        WRITE(DEBUG ONLY)
       PRM          NPRM          READ
       WRK          NWRK          WRITE

PROGRAMMER: D. E. BOLAND, CSC,       MARCH 1981
```

Subroutine WFILE

```
    SUBROUTINE WIND(POS,TPDW,IERR)

PURPOSE:
    WIND CONTROLS THE CALCULATION   OF THE WIND
    COMPONENTS U AND V AND THE WIND SPEED AND DIRECTION WS AND WD.

METHOD:
    1. RETRIEVE D/SD COEFFICIENTS AND LATITUDE GRADIENTS FOR
       THIS POINT FROM COMMON /INTCOM/.
    2. CALL DIGRAD TO CALCULATE THE LONGITUDINAL PRESSURE GRADIENT.
    3. CALL GWIND TO CALCULATE THE GEOSTROPHIC WIND.
    4. RETURN.

ARGUMENT LIST:
  ARGUMENT    TYPE    I/O    DESCRIPTION
    POS        R       I      ARRAY CONTAINING TRAJECTORY POINT:
                               POS(1)=ALTITUDE
                               POS(2)=LATITUDE
                               POS(3)=LOCAL SOLAR TIME
                               POS(4)=LONGITUDE
    TPDW       R      I/O     ARRAY CONTAINING CALCULATED PARAMETERS:
                               TPDW(1)=TEMPERATURE (K DEGREES, IN)
                               TPDW(2)=PRESSURE (N/M**2, IN)
                               TPDW(3)=DENSITY (KG/M**3, IN)
                               TPDW(4)=E-W WIND U (M/SEC, OUT)
                               TPDW(5)=N-S WIND V (M/SEC, OUT)
                               TPDW(6)=WIND SPEED (UNUSED)
                               TPDW(7)=WIND DIRECTION (UNUSED)
    IERR       I       O      ERROR FLAG:
                               =0, NO ERROR

CALLING SUBROUTINES:  MODELS

SUBROUTINES CALLED:  DIGRAD,GWIND

COMMON BLOCK PARAMETERS:
  COMMON NAME   PARAMETER   I/O   DESCRIPTION
   /USECOM/       IDBG       I      FLAG FOR DEBUG
                  BOUND      R      BOUNDARY BETWEEN UPPER AND LOWER
                                    ATMOSPHERIC MODEL SEGMENTS
   /INTCOM/       JZ         I      POINTER TO NEAREST ALTITUDE TO
                                     POS(1) IN ARRAY RETURNED BY DFLINT
                  VALINT     R      6X38 ARRAY CONTAINING VALUES OF
                                    GRADIENTS AND D/SD COEFFICIENTS
   /FILCOM/       NPRINT     I      PRINTED OUTPUT LUN

EXTERNAL DATA SETS USED:
      NAME          LUN       I/O OPERATIONS PERFORMED
      OUT           NPRINT     WRITE(DEBUG ONLY)

PROGRAMMER: D. E. BOLAND, CSC
```

Subroutine WIND

SUBROUTINE XALFA(ISEGM,Z,ZREF,PBOUND,ALFA,IERR)

PURPOSE:
XALFA COMPUTES INTEGRALS NECESSARY FOR ERROR ESTIMATIONS

METHOD:
1. COMPUTE INTEGRALS USING SUBROUTINE SIMP (INTEGRANDS PROVIDED BY SUBROUTINE GRAND).
2. RETURN

ARGUMENT LIST:

ARGUMENT	TYPE	I/O	DESCRIPTION
ISEGM	I	I	SEGMENT NUMBER MINUS ONE
Z	R	I	ALTITUDE (KM)
ZREF	R	I	REFERENCE ALTITUDE (KM): ALTITUDE FOR THE TOP BOUNDARY OF CURRENT SEGMENT
PBOUND	R	I	PRESSURE AT ZREF (N/M**2)
ALFA	R	O	AN ARRAY OF INTEGRALS
IERR	I	O	ERROR FLAG

CALLING SUBROUTINES: POLFIT, DCERR

SUBROUTINE CALLED: SIMP

COMMON BLOCK PARAMETERS USED: NONE

EXTERNAL DATA SETS USED: NONE

PROGRAMMER: T. LEE, CSC, SEPTEMBER 1981

Subroutine XALFA

SECTION 4 - LAIRS MATHEMATICAL SPECIFICATIONS

The mathematical details necessary for the LAIRS implementaion are presented in this section. Section 4.1 deals with the default atmospheric models. Section 4.2 discusses adjustments to the models on the basis of meteorological measurements, including least squares fitting procedures for vertical profiles, followed by the computation of atmospheric parameters in Section 4.3. Section 4.4 discusses error calculations, Section 4.5 describes the interpolation methods used in the LAIRS Program, and Section 4.6 describes a method of adjusting translational coefficients using meteorological data.

4.1 DEFAULT ATMOSPHERIC MODEL

The LAIRS default atmospheric model consists of three parts: the Edwards Air Force Base Reference Atmosphere, extending from the ground to approximately 25 kilometers; the 1972 Cospar International Reference Atmosphere (CIRA), extending from 25 kilometers to 110 kilometers; and the 1971 Jacchia-Roberts atmospheric model above 90 kilometers. Between 90 kilometers and 110 kilometers, either the CIRA or the Jacchia-Roberts model can be used. These models are described in the following sections and in References 2, 3, 5, and 6.

4.1.1 THE JACCHIA-ROBERTS MODEL

The Jacchia-Roberts atmospheric model determines the atmospheric mass density, ρ , and the number density of individual species, n_i, using the following two equations:

$$\frac{d}{dZ}(\ln \rho) = \frac{d}{dZ}\left(\ln \frac{\overline{M}}{T}\right) - \frac{\overline{M}\,g}{R^{*}T} \quad ; \quad Z \leq 100\,Km \qquad (4\text{-}1)$$

$$\frac{d}{dZ}(\ln n_i) = -(1+\alpha_i)\frac{d}{dZ}(\ln T) - \frac{M_i\,g}{R^{*}T} \quad ; \quad Z > 100\,Km \qquad (4\text{-}2)$$

where α_i = thermal diffusion coefficient of the species i

M_i = molecular weight of the species i

$\bar{M}$ = mean molecular weight

g = gravitational acceleration

R^* = universal gas constant

Equation (4-1) is the barometric equation and applies to the region of homogeneously mixed atmosphere below 100 kilometers, and Equation (4-2) is the diffusion equation for the number density of each individual species and applies to the atmosphere above approximately 100 kilometers, where the lighter species separate from the heavier species by the process of molecular diffusion.

The temperature, T, in Equations (4-1) and (4-2) must be known as a function of Z. Temperature-height profiles were empirically obtained in the Jacchia 1971 model and will be slightly modified according to the formulation given by Roberts so that the density equations can be integrated analytically (References 6 and 7).

The temperature profile to be used in the Jacchia-Roberts atmospheric density model takes the form of a fourth-order polynomial for heights from 90 kilometers to 125 kilometers and an exponential function of Z for heights above 125 kilometers.

$$T(Z) = T_x + (T_x - T_0) \sum_{n=1}^{4} a_n (Z - Z_x)^n \tag{4-3}$$

This equation gives temperatures between Z_0 and Z_x, and the coefficients a_n are determined from the following conditions:

$$
\begin{aligned}
T(Z_0) &= T_0: \text{ minimum temperature} \\
T(Z_x) &= T_x: \text{ temperature at the inflection point} \\
\left(\frac{dT}{dZ}\right)_{Z=Z_0} &= 0 \\
\left(\frac{dT}{dZ}\right)_{Z=Z_x} &= a_1(T_x-T_0) = 1.9\,\frac{(T_x-T_0)}{Z_x-Z_0} \quad : \text{ an empirical relation} \\
\left(\frac{d^2T}{dZ^2}\right)_{Z=Z_x} &= 2a_2(T_x-T_0) = 0
\end{aligned}
\tag{4-4}
$$

The four coefficients a_i $(i = 1\sim4)$ can be expressed in terms of Z_0, Z_x, T_0, and T_x as follows:

$$
\begin{aligned}
a_1 &= 1.9/(Z_x-Z_0) \\
a_2 &= 0 \\
a_3 &= -1.7/(Z_x-Z_0)^3 \\
a_4 &= -0.8/(Z_x-Z_0)^4
\end{aligned}
\tag{4-5}
$$

The values of Z_0 and Z_x are fixed at 90 kilometers and 125 kilometers, respectively. The value of T_0 was 183 K in the Jacchia 1971 model and was changed to 188 K in the Jacchia 1977 model. The quantity T_x is determined from the value of T_∞ (Reference 5).

$$T_x = a + bT_\infty + c\,e^{\bar{k}T_\infty} \tag{4-6}$$

where $a = 371.6678$

$b = 0.0518806$

$c = -294.3505$

$\bar{k} = -0.00216222$

For heights above 125 kilometers, Roberts used the following function to define the temperatures:

$$T(Z) = T_\infty - (T_\infty - T_x)\,\exp\left(-G_x \frac{Z - Z_x}{T_\infty - T_x} \cdot \frac{R_a + Z_x}{R_a + Z}\right) \qquad (4\text{-}7)$$

where G_x = temperature gradient at Z_x

R_a = 6356.766 kilometers = mean radius of the Earth

A temperature profile defined by Equations (4-3) and (4-7) is continuous at $Z = Z_x$ regardless of the choice of G_x. The temperature gradient will be continuous at $Z = Z_x$ if $G_x = 1.9(T_x - T_0)/(Z_x - Z_0)$. However, in the Jacchia-Roberts density model implemented in the Goddard Trajectory Determination System (GTDS), G_x was determined as a function of T_∞ such that the resulting density profiles obtained using Roberts' temperature profiles gave the best least-squares fit to Jacchia's tabulated density data. In this case, the temperature gradient is not continuous at $Z = Z_x$.

In addition to temperature profiles, Equations (4-1) and (4-2) require a knowledge of $g(Z)$ and $\bar{M}(Z)$. The following expressions were used for these quantities:

$$g(Z) = g_0 R_a^2 / (Z + R_a)^2 \qquad (4\text{-}8)$$

where g_0 = 9.80665 meters per second^2 and

$$\overline{M}(Z) = \sum_{n=0}^{6} C_n (Z-90) \qquad (90 < Z < 100) \tag{4-9}$$

The numerical values of C_n in this equation are given in Reference 5. Roberts analytically integrated Equations (4-1) and (4-2) using temperature profiles given by Equations (4-3) and (4-7), the gravitational acceleration, g(Z), and the mean molecular weight, $\overline{M}$(Z). The quantities g(Z) and $\overline{M}$(Z) are defined by Equations (4-8) and (4-9), respectively. The solutions obtained by Roberts, however, contain rather lengthy algebraic expressions and will not be given in this report. (See References 6 and 7 for further details).

Each temperature profile is labelled by the so-called exospheric temperature, T_∞, which sets the upper boundary value for the temperature. T_∞ is computed in three steps in the Jacchia-Roberts model. First, the nighttime minimum exospheric temperature, T_C, is obtained from the solar 10.7-centimeter flux level, using the relationship

$$T_c = 379^\circ + 3^\circ.24 \overline{F}_{10.7} + 1^\circ.3 (F_{10.7} - \overline{F}_{10.7}) \tag{4-10}$$

The second step involves computing T_{DNL}, the exospheric temperature that includes the diurnal variations, from T_C, i.e.,

$$T_{DNL} = T_N + (T_D - T_N) \cos^3 \frac{\tau}{2} \tag{4-11}$$

where

$$
\begin{aligned}
T_D &= T_c \left(1 + R \cos^m \tfrac{1}{2} | \theta - \delta | \right) \\
T_N &= T_c \left(1 + R \sin^m \tfrac{1}{2} | \theta + \delta | \right) \\
\tau &= H + \beta + p \sin (H + \gamma)
\end{aligned}
\tag{4-12}
$$

In these equations, H is the local solar time, θ is the latitude of the subsatellite point, and δ is the solar declination. The values of the parameters appearing in Equation (4-12) are:

$$
\begin{aligned}
m &= 2.2 \\
\beta &= -37^{\circ} \\
\rho &= 6^{\circ} \\
\gamma &= 43^{\circ}
\end{aligned}
$$

The contribution to T_∞ from the geomagnetic activity effect is given by

$$
\begin{aligned}
(\Delta T_\infty)_{GMG} &= 28^{\circ} K_p + 0.^{\circ}03\, e^{K_p} \quad (Z > 200\, Km) \\
&= 14^{\circ} K_p + 0.^{\circ}02\, e^{K_p} \quad (Z < 200\, Km)
\end{aligned}
\tag{4-13}
$$

where K_p is the 3-hour geomagnetic planetary index. An average time lag of $6.^{h}7$ was used for the time lag associated with the atmospheric variation resulting from the geomagnetic disturbance.

The total exospheric temperature is given by

$$
T_\infty = T_{DNL} + (\Delta T_\infty)_{GMG} \tag{4-14}
$$

The value of T_∞ uniquely determines the temperature profile to be used in the computation of the density, which will be further corrected for the semiannual and seasonal-latitudinal variations.

The Jacchia-Roberts atmospheric density model described above gives density and temperature. The pressure values are computed using the following relations:

$$P_{JR}(Z) = R^* T(z) \sum_{\ell} n_\ell(z) / N_A \qquad (Z > 100\,Km) \tag{4-15}$$

$$P_{JR}(Z) = R^* T(z) \rho_{JR}(z) / \overline{M}(z) \qquad (Z \leq 100\,Km) \tag{4-16}$$

When the mean molecular weight is desired at various altitudes, the following relations can be used:

$$\overline{M}(z) = \sum_{\ell} n_\ell(z) M_\ell \Big/ \sum_{\ell} n_\ell(z) \tag{4-17}$$

$$= RT(z) \rho_{JR}(z) / P_{JR}(z) \tag{4-18}$$

In these equations, $n_\ell(z)$ denotes the number density of an individual species given by Equation (4-2), and N_A denotes Avogadro's number.

4.1.2 THE CIRA 1972 AND ERA MODELS

The lower atmospheric part of the CIRA 1972 model (Reference 3) gives tabulated atmospheric parameters, i.e, temperature, pressure, density, and wind velocities at intervals of 5 kilometers in height, 10 degrees in latitude, and 1 month in time. Furthermore, the meteorological data used in the CIRA 1972 model has a high concentration near a latitude of

30 degrees north, which is in the neighborhood of the Shuttle reentry path. The lowermost 25 kilometers of the atmosphere are not covered by the CIRA 1972 model. For this region, the Edwards Air Force Base Reference Atmosphere (ERA) 1975 model (Reference 2), which was designed with the Shuttle reentry in mind, is recommended as the default model.

The combination of the CIRA 1972 and ERA 1975 models provides a general default lower atmospheric model for latitude 30 degrees north during the major portion of the Shuttle reentry and a more specific default model during the final descent phase into Edwards Air Force Base. These models are implemented in LAIRS in the form of tabulations on a permanent file.

4.1.3. DIURNAL, SEMIDIURNAL, AND LATITUDINAL VARIATIONS IN THE LOWER ATMOSPHERE

The diurnal and semidiurnal effects of CIRA 1972 can be incorporated in the following approximate manner. Let f(z,t) be an atmospheric parameter that is a function of altitude and local solar time, where f(z,t) is given approximately by

$$f(z,t) = A_0(z) + A_1(z)\cos\left\{\frac{\pi}{12}\left(t - t_1(z)\right)\right\} + A_2(z)\cos\left\{\frac{\pi}{6}\left(t - t_2(z)\right)\right\} \qquad (4\text{-}19)$$

where t is expressed in hours and

$A_0(z)$ = diurnal average of f(z,t)

$A_1(z)$ = diurnal amplitude at Z

$A_2(z)$ = semidiurnal amplitude at Z

$t_1(z)$ = time of the maximum diurnal effect at Z

$t_2(z)$ = time of the maximum semidiurnal effect at Z

The values of A_1, A_2, t_1, and t_2 are supplied graphically in the CIRA 1972 publication (Reference 3) and are tabulated on the LAIRS permanent file at 5-kilometer intervals. (The temperature coefficients given by CIRA are incomplete and have been interpolated in LAIRS to smoothly join the Jacchia model.) Because the values of the parameters tabulated by CIRA are not the average values A_0 that are required by Equation (4-19) but, rather, are values biased toward noon, the calculation of diurnal and semidiurnal effects in LAIRS takes the following form. First, the average $A_0(Z)$ is determined from the tabulated or interpolated $f(Z, t_R)$, where t_R represents the time of the reference tabulation (in this case, noon):

$$A_0(Z) = f(Z, t_R) - A_1(Z)\cos\left\{\frac{\pi}{12}(t_R - t_1(Z))\right\} - A_2(Z)\cos\left\{\frac{\pi}{6}(t_R - t_2(Z))\right\} \tag{4-20}$$

Once $A_0(Z)$ has been determined, it is substituted into Equation (4-19) to yield $f(Z, t_S)$, the value of the parameter f at any input time, t_S, corresponding to a Shuttle position.

The latitude variations of the atmospheric parameters have been incorporated in LAIRS in the form of latitude gradients stored on the permanent file at 5-kilometer intervals. These gradients, $g(f(Z, \theta))$, are simply the first derivatives in latitude of temperature, pressure, and density, as determined from the tabulated CIRA values in the region of 30 degrees north latitude:

$$g(f(Z,\theta_R)) = \left.\frac{\partial f(Z,\theta)}{\partial \theta}\right|_{\theta=\theta_R=30^\circ}$$
$$= \frac{f(Z,40^\circ) - f(Z,20^\circ)}{20^\circ} \tag{4-21}$$

Below 25 kilometers, the tabulated values of f (temperature, pressure, and density) used in the above calculation were taken from the Handbook of Geophysics (Reference 4), which gives tabulations at latitudes of 15 degrees and 45 degrees rather than at 20 degrees and 40 degrees.

Using these tabulated gradients, extrapolation of the value of any atmospheric parameter f to the Shuttle latitude, θ , is easily achieved using the following relationship:

$$f(Z,\theta_S) = f(Z,\theta_R)\cdot\left[1 + g(f(Z,\theta_R))\cdot(\theta_S - \theta_R)\right] \tag{4-22}$$

This calculation is generally used only below 90 kilometers, where θ_S is always relatively close to 30 degrees north latitude, the default value of the reference latitude.

Although the values of the diurnal and semidiurnal coefficients and latitude gradients are tabulated in the LAIRS permanent file at 5-kilometer intervals (as are the values of the parameters themselves), they, like the parameters, are always interpolated to yield a smooth output.

4.2 ADJUSTED ATMOSPHERIC MODEL

Both the upper and lower atmospheric models can be adjusted on the basis of meteorological data. For the lower model, which in its default form consists of simple tabular data, adjustment is achieved by fitting a set of polynomials to the meteorological data (in accordance with the gas law and hydrostatic equilibrium, unless the user selects otherwise). Alternatively, the user may elect simply to interpolate from the meteorological data. For the Jacchia-Roberts model, the boundary values of temperature and density at 90 kilometers are adjusted to agree with the data and to be continuous with the lower atmospheric model. Section 4.2.1 discusses the Jacchia-Roberts model adjustments, and Section 4.2.2 describes the methods used in the polynomial fitting of the lower atmospheric parameters.

4.2.1 JACCHIA-ROBERTS MODEL ADJUSTMENTS

Atmospheric parameters computed using the Jacchia-Roberts model depend on the temperature and density values at the lower boundary (90 kilometers) of the Jacchia-Roberts model. In LAIRS, these boundary values are reset in such a way that the continuity of the computed atmospheric parameters is satisfied at the boundary. A similar readjustment of the density value at 100 kilometers is also needed because the Jacchia-Roberts formulation has an internal segment boundary at 100 kilometers that is affected by adjustments made at 90 kilometers. Boundary value readjustments at 90 kilometers are carried out by replacing the original Jacchia-Roberts values with the temperature and density values at 90 kilometers obtained using the polynomial fitting procedure for the lower part of the atmosphere (below 90 kilometers). In the case of temperature, the replacement is simple; $T(90)$, the Jacchia-Roberts default boundary temperature, is replaced by $T_p(90)$, the polynomial adjusted boundary temperature.

In the case of density, however, simply replacing the Jacchia-Roberts default boundary density $\rho(90)$ with the polynomial adjusted density, $\rho_p(90)$, is insufficient, because the Jacchia-Roberts model makes additional corrections (for geomagnetic, seasonal, and latitudinal effects) to the density. This means that the final density value output by the model at 90 kilometers is not equal to the input boundary value at that height, but rather is a corrected density of the form

$$\rho_c(90) = \rho_p(90) \cdot \alpha \tag{4-23}$$

where α denotes a correction factor that has a value close to 1 and is assumed to be independent of $\rho_p(90)$.

LAIRS uses a two-step procedure to ensure that density is continuous across the boundary. First, the Jacchia-Roberts model is run with the polynomial adjusted density $\rho_p(90)$ as the boundary value. From the output $\rho_c(90)$, the value of α is determined:

$$\alpha = \frac{\rho_c(90)}{\rho_p(90)} \tag{4-24}$$

Second, using the factor α, a new boundary value of density, $\rho_p'(90)$, is defined as

$$\rho_p'(90) = \frac{\rho_p(90)}{\alpha} \tag{4-25}$$

The quantity $\rho_p'(90)$ is then used as the density boundary value in all future Jacchia-Roberts calculations. It yields a Jacchia-Roberts output density value at 90 kilometers that is equal to the polynomial density value $\rho_p(90)$.

The 100-kilometer density value is linearly proportional to the 90-kilometer density value and is always computed using the Jacchia-Roberts density value at 90 kilometers. Thus, the 100-kilometer density is readjusted by scaling the density value at 100 kilometers obtained using the Jacchia-Roberts model with the ratio of $\rho_p'(90)$, which is the new boundary density at 90 kilometers, over $\rho_p(90)$, which is the polynomial adjusted density at 90 kilometers.

4.2.2 POLYNOMIAL MODEL ADJUSTMENTS

The idea behind the adjusted polynomial model is that the best approximation for temperature, pressure, and density in the entire lower atmospheric region (below 90 kilometers) can be achieved by combining the available meteorological data into a reference profile that can then be subjected to least squares polynomial fitting. The entire altitude range is divided into four segments, as shown in Figure 4-1. The Jacchia-Roberts model is used in the uppermost segment and the polynomial model is used in the lower three segments.

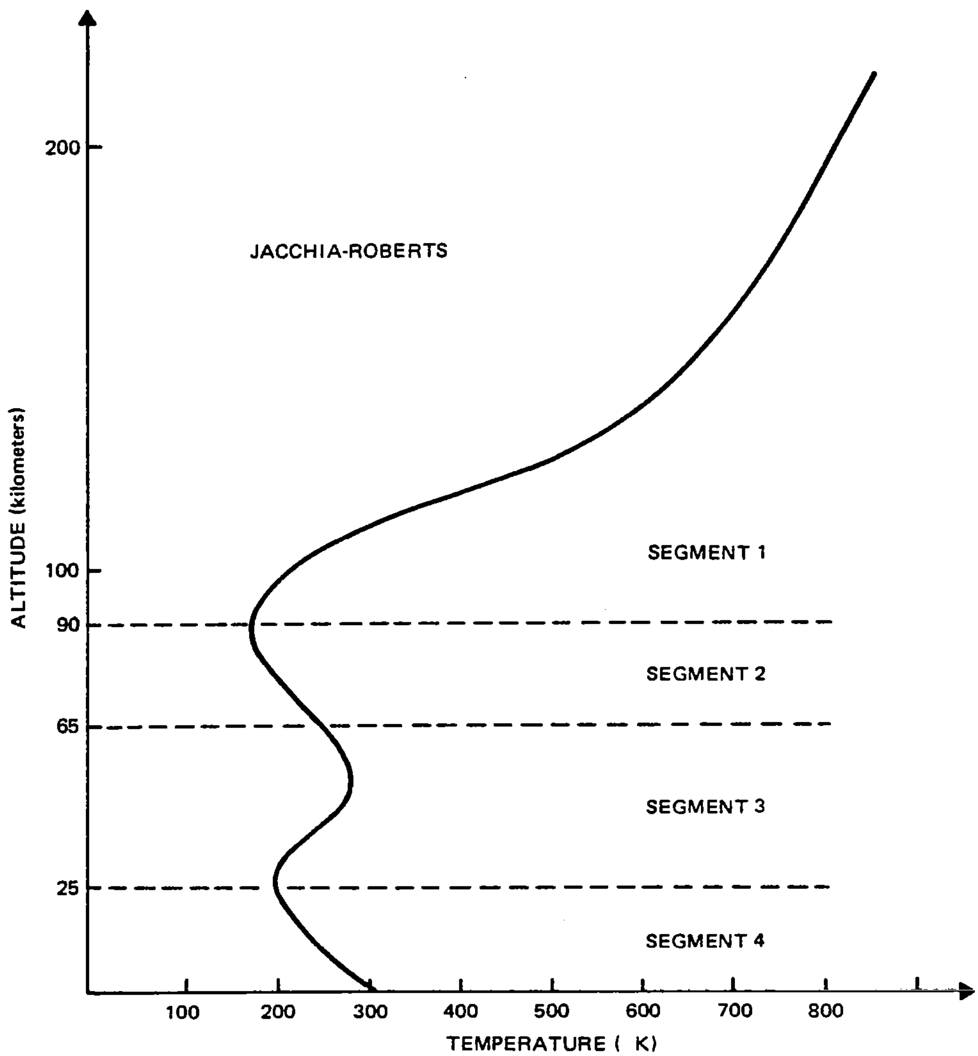

Figure 4-1. Definition of Altitude Segments

In each of the three segments of the polynomial model, third-order polynomials are fitted to temperature and to the logarithms of pressure and density. The segment boundaries may be chosen by the user; their default values are 90 kilometers, 65 kilometers, and 25 kilometers.

Input meteorological data are received in the form of separate vertical profiles taken at different times and different places near the Shuttle reentry trajectory. Before these data can be combined for fitting, they must be transformed to a common latitude and local solar time. This is achieved by means of the diurnal and semidiurnal coefficients and latitude gradients discussed in Section 4.1.3. The reference latitude and local solar time may be selected by the user, but default values of 30 degrees north latitude and local noon are supplied. Once the reference profile has undergone fitting, the diurnal and semidiurnal coefficients and latitude gradients are used to translate from the reference position to the Shuttle position.

Two different procedures are used to fit the reference profiles for the lower atmosphere. In the first scheme, temperature, pressure, and density data are directly fitted to a set of polynomials. There are three different polynomials for each segment: one for temperature, one for pressure, and one for density. In the second scheme, only the temperature polynomials are constructed, using temperature, pressure, and density data or using any combination of these three data types. In this procedure, the pressure and density values are derived from the temperature polynomials using the ideal gas law and the barometric equation. Details of these two procedures are given in Sections 4.2.2.1 and 4.2.2.2.

4.2.2.1 Independent Polynomial Fittings for Temperature, Pressure, and Density Profiles

In this procedure, temperature, pressure, and density polynomials are constructed independently using the corresponding meteorological profiles. The continuity condition is not imposed on the fitted atmospheric parameters at the boundary between two segments.

Let F(Z) be the polynomial function of Z to be fitted to the meteorological profile $f(Z_n)$. For pressure and density, $f(Z_n)$ will be the natural log value of the observed data.

$$F(Z) = A_0 + \sum_{k=1}^{3} A_K (Z_R - Z)^k \tag{4-26}$$

$$\begin{aligned} f(Z_n) &= T_{OBS}(Z_n) && \text{for temperature} \\ &= \ln(P_{OBS}(Z_n)) && \text{for pressure} \\ &= \ln(\rho_{OBS}(Z_n)) && \text{for density} \end{aligned} \tag{4-27}$$

Z_R, appearing in the expression for F(Z), denotes a reference altitude. In the current version of LAIRS, Z_R is defined as the upper boundary altitude of the segment. Then A_0 becomes the upper boundary value of the computed atmospheric parameter. A set of coefficients (A_0, A_1, A_2, A_3) will be independently determined for temperature, pressure, and density.

In the least squares fitting procedure, the sum of the squares of the weighted residuals is minimized, i.e.,

$$Q(\vec{A}) = \sum_{n=1}^{M} \left[w_n \left(f(z_n) - F(z_n) \right) \right]^2 \tag{4-28}$$

where A denotes the array A_i ($i = 0 \sim 3$) and ω_n is the weighting factor for the residual, $F_{OBS}(Z_n) - F(Z_n)$. The weighting factors used here are computed using the measurement uncertainty $\Delta f(Z_n)$

$$w_n = 1/\Delta f(z_n) \tag{4-29}$$

where $\Delta f(Z_n)$ is the measurement uncertainty associated with the nth observation. For the case of temperature, $\Delta f(Z_n)$ is taken to be σ_n, the measurement standard deviation. (If no standard deviation is reported, a default value of 5 percent is assumed; however, the user may change this value via the DCEDIT keyword card.) For pressure, the uncertainty for $\ln(P_n)$ is defined as

$$\Delta f(z_n) = \ln \left[1 + \frac{\sigma_n}{P_n} \right] \tag{4-30}$$

where σ_n and P_n denote the σ and P values at $Z = Z_n$.

This expression was derived from the following simple consideration. If P is expressed as

$$P = \bar{P} + \Delta P$$

the corresponding expression in terms of $\ell n(P)$ will be

$$\ell n P = \ell n \bar{P} + \ell n \left[1 + \frac{\Delta P}{\bar{P}} \right] \qquad (4\text{-}31)$$

Thus, $\ell n(1 + (\Delta P/\bar{P}))$ can be interpreted as the uncertainty associated with the measurement of $\ell n(P)$.

The polynomial coefficients A_i $(i = 0 \sim 3)$ will be determined when $Q(\bar{A})$ is minimized with respect to A_i. This is done using subroutine LSQPOL, which is available in the CDC system library at LaRC. Mathematical details of this procedure will not be given here, since it is a special case of the procedure presented in Section 4.2.2.2.

4.2.2.2 Determination of Temperature Polynomials Using a Differential Correction Procedure With Temperature, Pressure, and Density Data

In this section, a differential correction procedure that determines a set of temperature coefficients and a boundary pressure value is described. This procedure involves minimizing the sum of the squares of the weighted residuals of temperature, pressure, and density with respect to temperature coefficients and the boundary pressure values.

The sum of the squared weighted residuals to be minimized is given by

$$Q(\bar{S}) = Q^{(T)}(\bar{S}) + Q^{(P)}(\bar{S}) + Q^{(D)}(\bar{S}) \tag{4-32}$$

where $Q^{(T)}$, $Q^{(P)}$, and $Q^{(D)}$ denote the contribution to Q from temperature, pressure, and density, respectively. The solve-for parameter vector $\bar{S}$ is defined as a column vector consisting of temperature coefficients and the boundary pressure value. The transpose of $\bar{S}$ is given by

$$\bar{S}^t = (A_1, A_2, A_3, A_0, \ln P_0) \tag{4-33}$$

The temperature polynomial is defined by Equation (4-26). $Q^{(T)}(\bar{S})$, $Q^{(P)}(\bar{S})$, and $Q^{(D)}(\bar{S})$ are given by

$$Q^{(T)}(\bar{s}) = \sum_{n} \left[w_n^{(T)} \left(T_{OBS}(z_n) - T(z_n) \right) \right]^2 \tag{4-34a}$$

$$Q^{(P)}(\bar{s}) = \sum_{n} \left[w_n^{(P)} \left(\tilde{P}_{OBS}(z_n) - \tilde{P}(z_n) \right) \right]^2 \tag{4-34b}$$

$$Q^{(D)}(\bar{s}) = \sum_{n} \left[w_n^{(D)} \left(\tilde{\rho}_{OBS}(z_n) - \tilde{\rho}(z_n) \right) \right]^2 \tag{4-34c}$$

In these equations, the following notations were used.

$$T(z) = T(z, \bar{s}) = A_0 + \sum_{k=1}^{3} A_k (z_0 - z)^k \tag{4-35}$$

$$\tilde{P}_{OBS}(z_n) = \ln (P_{OBS}(z_n)) \tag{4-36a}$$

$$\tilde{\rho}_{OBS}(z_n) = \ln (\rho_{OBS}(z_n)) \tag{4-36b}$$

$$\tilde{P}(z_n) = \ln P_o - \int_{z_o}^{z_n} \frac{g(z)\overline{M}}{R^* T(z)} dz \tag{4-37a}$$

$$\tilde{\rho}(z_n) = \ln \left(\frac{P_o \overline{M}}{R^* T(z_n)}\right) - \int_{z_o}^{z_n} \frac{g(z)\overline{M}}{R\,T(z)} dz \tag{4-37b}$$

where g(Z), which appears in the integrands of $\tilde{P}$ and $\tilde{\rho}$, is the gravitational acceleration at the altitude Z and is computed using an approximate equation:

$$g(z) = g_s\left(\frac{R_e}{R_e + Z}\right)^2 \tag{4-38}$$

where g_s is the gravitational acceleration at Z = 0 and R_e is an effective radius of the Earth.

Below 90 kilometers, a constant mean molecular wieght, $\overline{M}$, is used throughout.

Using two column vectors, $\overline{f}$ and $\overline{F}(\overline{S})$, and a diagonal matrix W, the function $Q(\overline{S})$ can be expressed as

$$Q(\bar{s}) = (\bar{f} - \bar{F}(\bar{s}))^t \, W \, (\bar{f} - \bar{F}(\bar{s})) \tag{4-39}$$

where $\overline{f}$, $\overline{F}$, and W are defined as follows:

$$\begin{aligned} \bar{f}^{\,t} = \{ & T_{OBS}(z_1), T_{OBS}(z_2), \cdots, T_{OBS}(z_N); \\ & \widetilde{P}_{OBS}(z'_1), \widetilde{P}_{OBS}(z'_2), \cdots, \widetilde{P}_{OBS}(z'_{N'}); \\ & \widetilde{\rho}_{OBS}(z''_1), \widetilde{\rho}_{OBS}(z''_2), \cdots, \widetilde{\rho}_{OBS}(z''_{N''}) \} \end{aligned} \tag{4-40}$$

$$\begin{aligned} \bar{F}(\bar{s})^t = \{ & T(z_1), T(z_2), \cdots, T(z_N); \\ & \widetilde{P}(z'_1), \widetilde{P}(z'_2), \cdots, \widetilde{P}(z'_{N'}); \\ & \widetilde{\rho}(z''_1), \widetilde{\rho}(z''_2), \cdots, \widetilde{\rho}(z''_{N''}) \} \end{aligned} \tag{4-41}$$

$$
\begin{aligned}
W_{ii} &= (w_i^{(T)})^2 \qquad 1 \le i \le N \\
&= (w_i^{(P)})^2 \qquad N+1 \le i \le N+N' \\
&= (w_i^{(D)})^2 \qquad N+N'+1 \le i \le N_t \\
W_{ij} &= 0 \qquad (i \neq j)
\end{aligned}
\tag{4-42}
$$

where N_t denotes the total number of observations included, i.e., $N_t = N + N' + N''$, and $\{Z_n : n = 1 \sim N\}$, $\{Z'_n : n = 1 \sim N'\}$, and $\{Z''_n : n = 1 \sim N''\}$ denote arrays of altitude points associated with temperature, pressure, and density observations, respectively. These three arrays are taken to be identical in LAIRS.

In general, $\bar{F}(\bar{S})$ is not a linear function of $\bar{S}$. The differential correction procedure presented here involves linearizing $\bar{F}(\bar{S})$ using the Taylor expansion:

$$
\bar{F}(\bar{S}) = \bar{F}(\bar{S}_o) + B\,\Delta\bar{S} \tag{4-43}
$$

where

$$
B = \left(\frac{\partial \bar{F}}{\partial \bar{S}}\right)_{\bar{S}=\bar{S}_o} ; \ N_t \times N_s \text{ matrix} \tag{4-44}
$$

and

$$\Delta\bar{S} = \bar{S} - \bar{S}_0 \tag{4-45}$$

N_t and N_s denote the total number of observations and the total number of solve-for parameters, respectively.

Using Equation (4-43) in Equation (4-39), a Q-function that is quadratic in $\Delta\bar{S}$ is obtained, i.e.,

$$Q_L(\Delta\bar{S}) = (\Delta\bar{f} - B\Delta\bar{S})^t W (\Delta\bar{f} - B\Delta\bar{S}) \tag{4-46}$$

where

$$\Delta\bar{f} = \bar{f} - \bar{F}(\bar{S}_0) \tag{4-47}$$

The function $Q_L(\Delta\bar{S})$ is readily minimized with respect to $\Delta\bar{S}$. The vector $\Delta\bar{S}$ that minimizes $Q_L(\Delta\bar{S})$ is given by

$$\Delta\bar{S} = (B^t W B)^{-1} B^t W \Delta\bar{f} \tag{4-48}$$

$\bar{S}$ can then be determined as follows:

$$\bar{S} = \bar{S}_o + \Delta\bar{S} \tag{4-49}$$

This process is repeated with $\bar{S}$ as a new $\bar{S}_0$ until $\Delta\bar{S}$ becomes smaller than a prescribed tolerance limit. If $\bar{F}(\bar{S})$ is a linear function of $\bar{S}$, i.e., $\bar{F}(\bar{S}) = \bar{F}_0 + B\bar{S}$, then the $\bar{S}$ that minimizes $Q(\bar{S})$ is given by

$$\bar{S} = (B^t W B)^{-1} B^t W \Delta\bar{f} \tag{4-50}$$

where

$$\Delta\bar{f} = \bar{f} - \bar{F}_o \quad .$$

In this case, the complete answer is obtained in one step and no iteration is required. The procedure used in Section 4.2.2.1 corresponds to the case where $\bar{F}(\bar{S})$ is a linear function of $\bar{S}$.

In order to compute $\Delta\bar{S}$ in Equation (4-48), the matrix B must be evaluated. From the definition given in Equation (4-44), B_{nk}, the (n,k) component of B, is given by

$$B_{nk} = \left(\frac{\partial F(Z_n, \bar{S})}{\partial S_k} \right)_{\bar{S} = \bar{S}_o} \tag{4-51}$$

There are three different types of partial derivatives of this kind. The first type consists of the partial derivatives of the model temperature given in Equation (4-35) with respect to $\bar{S}$. (See Equation (4-33) for the definition of $\bar{S}$), i.e.,

$$\begin{aligned} B_{nk} &= \left(\frac{\partial T(Z_n, \bar{S})}{\partial S_k} \right) \\ &= (Z_o - Z_n)^k \qquad : \quad k = 1 \sim 3 \\ &= 1 \qquad\qquad\quad\;\; : \quad K = 4 \\ &= 0 \qquad\qquad\quad\;\; : \quad K = 5 \end{aligned} \tag{4-52}$$

The second type of partial derivatives consists of the model pressure partial derivatives with respect to $\bar{S}$. Using the definition of $\tilde{P}(Z)$ given in Equation (4-37a), these partial derivatives are computed as follows:

$$
\begin{aligned}
B_{n'k} &= \left(\frac{\partial \tilde{P}(z'_{n'}, \bar{s})}{\partial s_k} \right)_{\bar{s}=\bar{s}_0} \\
&= \int_{z_0}^{z'_{n'}} \frac{g(z)\,\bar{M}}{R^*[T(z,\bar{s}_0)]^2} \cdot \left(\frac{\partial T(z,\bar{s})}{\partial s_k} \right)_{\bar{s}=\bar{s}_0} dz \qquad ; \ k = 1 \sim 4 \\
&= 1 \qquad\qquad ; \ k = 5
\end{aligned}
\tag{4-53}
$$

Similarly, the third type of partial derivatives, the density partial derivatives, are given by

$$
\begin{aligned}
B_{n''k} &= \left(\frac{\partial \tilde{P}(z''_{n''}, \bar{s})}{\partial s_k} \right)_{s=\bar{s}_0} \\
&= -\frac{1}{T(z''_{n''},\bar{s}_0)} \left(\frac{\partial T(z''_{n''},\bar{s})}{\partial s_k} \right)_{\bar{s}=\bar{s}_0} + \int_{z_0}^{z''_{n''}} \frac{g(z)\,\bar{M}}{R^*[T(z,\bar{s}_0)]^2} \cdot \left(\frac{\partial T}{\partial s_k} \right)_{\bar{s}=\bar{s}_0} dz \\
&\qquad ; \ k = 1 \sim 4 \\
&= 1 \qquad ; \ k = 5
\end{aligned}
\tag{4-54}
$$

4.3 COMPUTATION OF ATMOSPHERIC PARAMETERS

The final readjusted model vertical profile of an atmospheric parameter is given by Equation (4-26) in the case of independent polynomial fitting. The same equation will be used for temperature, pressure, and density, with an appropriate set of coefficients for each segment. In the case of combined fitting of temperature, pressure, and density data, the readjusted temperature profile is given by Equation (4-35). Pressure and density at a particular altitude are computed from the temperature profile and the boundary pressure value using the gas law and the barometric equation. Atmospheric parameters computed in this manner correspond to a reference latitude, θ_R, and a reference local solar time, t_R. Thus, an atmospheric parameter computed at (Z, θ_R, t_R) is denoted as $F(Z, \theta_R, t_R)$. The computation of the same atmospheric parameter at a Shuttle position (Z_s, θ_s, Φ_s) and a Greenwich mean time of τ necessitates diurnal, semidiurnal, and latitudinal translations as described in Section 4.1.3. Equations (4-19), (4-20), and (4-22) are used in this process (the values of θ_R and t_R in the equations are now those associated with the location of the reference profile). Following these corrections, temperature, pressure, and density may no longer strictly obey the gas law because of uncertainties in the translational coefficients and gradients. The percentage deviation from the gas law of these translated values is computed by deriving the value of the gas constant R* from these values and comparing it with the known value:

$$R_1^* = \frac{P\overline{M}}{\rho T} \tag{4-55}$$

$$\delta = \frac{R_1^* - R^*}{R^*} \times 100 \qquad (4\text{-}56)$$

where R_1^* is the derived value of the gas constant and γ is the percent deviation, which is reported in the LAIRS output. Temperature, pressure, density, and mean molecular weight are designated by T, P, ρ, and $\overline{M}$, respectively. To ensure a set of parameters that are consistent with the gas law, LAIRS recalculates the temperature from the translated values of pressure and density as a final step (temperature was chosen because the diurnal coefficients for temperature are the least well known) simply by

$$T = \frac{P\overline{M}}{\rho R^*} \qquad (4\text{-}57)$$

The user may set a keyword card (LOWMOD) to skip this final temperature correction if the correction is not desired.

In addition to the percent deviation, LAIRS prints out the values of the mean molecular weight, $\overline{M}$, and the pressure scale height, H_p. The latter is calculated as

$$H_p = \frac{R^* T}{\overline{M}\, g} \tag{4-58}$$

where g is the acceleration of gravity and is given by Equation (4-8). The mean molecular weight reported above 90 kilometers is the value given for the Jacchia-Roberts model by Equation (4-9), while below 90 kilometers it is simply the sea level value of 28.9644 grams/mole.

Two other parameters are derived by LAIRS from the calculated values of temperature, pressure, and density. These are the Shuttle Mach number m and the estimated onboard pressure measurement P_n. The Mach number is merely the ratio of the Shuttle speed, V, to the speed of sound c:

$$m = \frac{V}{c} = \frac{V}{\sqrt{\dfrac{\gamma R^* T}{\overline{M}}}} \tag{4-59}$$

For air, $\gamma = 1.4$. The onboard pressure measurement is derived via a set of equations that are valid for a body with the aerodynamic characteristics of the Shuttle. First, the coefficient of pressure, C_p, is calculated as

$$C_p = 1.84\left(\cos(61^\circ - \alpha)\right)^n \tag{4-60}$$

where α is the angle of attack of the Shuttle and

$$n = 2.7 - \frac{1.5}{m^2} \tag{4-61}$$

The dynamic pressure, $\bar{q}$, is then given by

$$\bar{q} = \frac{1}{2}\rho V^2 \tag{4-62}$$

and the onboard pressure measurement is given by

$$P_N = P + \bar{q} C_p \tag{4-63}$$

where P and ρ are the free stream pressure and density (i.e., the values of pressure and density determined by LAIRS, respectively). As the Shuttle speed decreases during reentry, these equations break down between Mach 2 and Mach 1; however, they are reported down to Mach 1 by LAIRS.

Finally, LAIRS must produce values for the wind components. These are not modeled in any way; they are merely interpolated from the meteorological data with no attempt at diurnal or latitudinal translation. It should be recognized that while this approach cannot guarantee accurate values for the wind components, it was the only viable alternative available (see Reference 1). However, the option of calculating wind components using the geostrophic wind equations is provided in LAIRS (see Reference 1). This technique requires the use of diurnal and semidiurnal coefficients and latitude gradients, which are, of course, default values.

4.4 COMPUTATION OF UNCERTAINTIES ASSOCIATED WITH ATMOSPHERIC PARAMETERS

An atmospheric parameter is computed using a function F of the altitude, Z, and the solve-for parameters, $\overline{S}$:

$$F = F(z, \overline{S}) \tag{4-64}$$

The solve-for parameters, $\overline{S}$, are obtained through a differintial correction procedure. The variance-covariance matrix of $\overline{S}$ is available from the differential correction procedure and used to obtain an approximate variance of F, v(F), where

$$v(F) = \left(\frac{\partial F}{\partial \bar{S}}\right) C(\bar{S}) \left(\frac{\partial F}{\partial \bar{S}}\right)^t \tag{4-65}$$

In this equation, $C(\bar{S})$ represents the variance-covariance matrix, and $(\partial F/\partial \bar{S})$ represents a column vector of partial derivatives of F with respect to $\bar{S}$ computed using the converged differential correction solution. In a normal differential correction procedure, five parameters are determined for the top segment of the lower atmosphere, but only three parameters each are determined for the middle and bottom segments. The upper boundary temperature and pressure of the two lower segments are not solved for but are computed using the solutions for the upper segment. Thus, a normal differential correction process in LAIRS yields a 5x5 variance-covariance matrix for the top segment and a 3x3 variance-covariance matrix for each of the two lower segments. Contributions to the variance of F from uncertainties associated with the computed boundary temperature and pressure can be obtained in the following way. First, the variance-covariance matrix of the fixed boundary temperature and pressure is computed using the solutions of the upper segment. Then, the direct sum of the 3x3 variance-covariance matrix of the differential correction process and the computed 2x2 variance-covariance matrix is formed. The resultant 5x5 matrix will be used in Equation (4-65) to obtain v(F).

The estimated uncertainty of F, ΔF, is obtained from

$$\Delta F = \sqrt{v(F)} \tag{4-66}$$

and printed out in the LAIRS Output Report, Part I. The explicit forms of $F(Z,\bar{S})$, $\partial F/\partial \bar{S}$, and $C(\bar{S})$ that are used in LAIRS are listed below:

$$\bar{S}^t = (A_1, A_2, A_3, A_0, \ln P_0)$$

$$\bar{A}^t = (A_1, A_2, A_3, A_0)$$

$$T(z) = A_0 + A_1(z_0-z) + A_2(z_0-z)^2 + A_3(z_0-z)^3$$

$$\ln\left[\frac{P(z)}{P_0}\right] = -\int_{z_0}^{z} \frac{g\bar{M}}{R^* T}\, dz$$

$$\ln\left[\frac{\rho(z)}{\rho_0}\right] = \ln\left[\frac{T_0}{T(z)}\right] - \int_{z_0}^{z} \frac{g\bar{M}}{R^* T}\, dz$$

$$\left(\frac{\partial T}{\partial \bar{S}}\right)^t = \left((z_0-z), (z_0-z)^2, (z_0-z)^3, 1, 0 \right)$$

$$\left(\frac{\partial P}{\partial \bar{S}}\right)^t = P\left(\int_{z_0}^{z} \frac{1}{T}\left(\frac{\partial T}{\partial \bar{A}}\right)^t \frac{g\bar{M}}{R^* T}\, dz \,,\, 1 \right)$$

$$\left(\frac{\partial \rho}{\partial \bar{S}}\right)^t = \rho\left(\int_{z_0}^{z} \frac{1}{T}\left(\frac{\partial T}{\partial \bar{A}}\right)^t \frac{g\bar{M}}{R^* T}\, dz - \frac{1}{T}\left(\frac{\partial T}{\partial \bar{A}}\right)^t ,\, 1 \right)$$

$$C(\bar{S}) = (B^t W B)^{-1} \quad : \text{ for the top segment*}$$

$$= \begin{pmatrix} C(\vec{A}') & \vdots & O \\ \cdots\cdots & \vdots & \cdots\cdots \\ O & \vdots & C(\vec{\beta}) \end{pmatrix} \text{ for the two lower segments}$$

where $C(\bar{A}')$ = 3x3 variance-covariance matrix of
$\bar{A}' = (A_1, A_2, A_3)^t$ and
$C(\vec{\beta})$ = 2x2 variance-covariance matrix of
$\vec{\beta} = (A_0, \ln(P_0))^t$ and

$$C(\vec{\beta}) = \begin{pmatrix} \left(\frac{\partial A_0}{\partial \bar{S}'}\right)^t C(\bar{S}')\left(\frac{\partial A_0}{\partial \bar{S}'}\right) & \left(\frac{\partial A_0}{\partial \bar{S}'}\right)^t C(\bar{S}')\left(\frac{\partial \ln P_0}{\partial \bar{S}'}\right) \\ \left(\frac{\partial \ln P_0}{\partial \bar{S}'}\right)^t C(\bar{S}')\left(\frac{\partial A_0}{\partial \bar{S}'}\right) & \left(\frac{\partial \ln P_0}{\partial \bar{S}'}\right)^t \cdot C(\bar{S}')\left(\frac{\partial \ln P_0}{\partial \bar{S}'}\right) \end{pmatrix}$$

where $\bar{S}'$ indicates the five-parameter array of the upper section.

Somewhat different types of error estimations for the polynomial fitting scheme discussed in this section can be obtained using the average weighted residuals (O-C) and the weighted root-mean-square (WRMS) values for the temperature residuals, the log pressure residuals, and the log density residuals. First, the standard deviation of the weighted

*See Section 4.2.2 for definitions of B and W.

residuals for temperature, log pressure, and log density is given by:

$$\text{Standard Deviation of Weighted Residuals} = \sqrt{(\text{Weighted RMS})^2 - (\text{Average Weighted Residual})^2} \tag{4-67}$$

Second, the WRMS values of the residuals can be used to estimate an average percentage deviation of the computed temperature, pressure, and density from the corresponding observed values, i.e.,

$$\frac{\delta T}{T} \approx \text{WRMS}(T) \times \frac{\sigma(T)}{T}$$

$$\frac{\delta P}{P} \approx \exp\left\{ \text{WRMS}(\ln P) \times \ln\left(1 + \frac{\sigma(P)}{P}\right)\right\} - 1 \tag{4-68}$$

$$\frac{\delta \rho}{\rho} \approx \exp\left\{ \text{WRMS}(\ln \rho) \times \ln\left(1 + \frac{\sigma(\rho)}{\rho}\right)\right\} - 1$$

where σ represents the uncertainty assumed for each measurement type.

In a typical differential correction run, σ(F)/F (where F denotes temperature, pressure, or density) is assumed to be

0.05 and the WRMS values are in the neighborhood of 0.5. Thus, for all three cases, the approximate percentage departure of the computed value from the observed value is given by

$$\frac{\delta F}{F} \approx \text{WRMS} \times \left(\frac{\sigma(F)}{F} \right) \tag{4-69}$$

If $\sigma(F)/F$ is not a constant in a given segment, an average of this quantity for the segment can be used in this error estimation.

4.5 INTERPOLATION METHODS

The LAIRS Program incorporates two different types of interpolation, depending upon the type of input data used. This input data can be either the default atmospheric data or observed meteorological data.

4.5.1 DEFAULT DATA

The default interpolation mode uses data supplied on the atmospheric data working file. Either a first-order or second-order Lagrangian interpolation in altitude can be used by calling the LaRC CDC library subroutine IUNI. A matrix consisting of values of temperature, pressure, density, and wind components for six different altitudes is passed to subroutine IUNI for interpolation. If Y_1, Y_2, ..., Y_N are the values of the function evaluated at the tabulated values X_1, X_2, ..., X_N of the independent variable (altitude), then the interpolation equations used are as follows.

1. First order:

$$Y_0 = y_i + \frac{(y_{i+1} - y_i) \cdot (x_0 - x_i)}{(x_{i+1} - x_i)} \qquad (4\text{-}70)$$

$$x_i \leq x_0 \leq x_{i+1}$$

2. Second order:

$$Y_0 = \frac{1}{(x_{i+2} - x_i)} \cdot \left[\frac{(y_i(x_{i+1} - x_0) - y_{i+1}(x_i - x_0)) \cdot (x_{i+2} - x_0)}{(x_{i+1} - x_i)} \right. \qquad (4\text{-}71)$$

$$\left. \frac{(y_{i+1}(x_{i+2} - x_0) - y_{i+2}(x_{i+1} - x_0)) \cdot (x_i - x_0)}{(x_{i+2} - x_{i+1})} \right]$$

where the index i is chosen so that $|X_0 - X_i| + |X_0 - X_{i+1}|$ is a minimum.

These equations are only used for the temperature and the wind components. The pressure and density are interpolated using the following logarithmic relationship

$$f(h) = f(h_i) \exp\left[\frac{h_i - h}{h_i - h_{i+1}} \ln\left(\frac{f(h_{i+1})}{f(h_i)} \right) \right] \qquad (4\text{-}72)$$

$$h_i \leq h \leq h_{i+1}$$

where h is the altitude.

4.5.2 METEOROLOGICAL DATA

When meteorological profiles based on observational data are available, the user has several options. If more than one meteorological profile is available, then each profile is interpolated in altitude using the technique described in Section 4.5.1. After each profile has been interpolated in altitude, the points from each profile corresponding to a given altitude can be interpolated again in latitude and longitude or in latitude and local solar time.

If the user chooses to interpolate in latitude and longitude, a simple univariate interpolation scheme is used to obtain temperature, pressure, density, wind speed, and wind direction between the meteorological profiles. This scheme is based on the great circle arc lengths from the Shuttle position to each of two meteorological profiles. The equation used to obtain the interpolated values is as follows

$$f(C_s) = \frac{C_{12} - C_s}{C_{12}} f_1 + \frac{C_s}{C_{12}} f_2 \qquad (4\text{-}73)$$

where C_{12} = great circle arc length between the two meteorological profiles

C_S = great circle arc length from the first profile to the Shuttle position

f_1 = parameter value at first profile

f_2 = parameter value at second profile

The user can also specify a bivariate interpolation in latitude and local solar time for temperature, pressure, and density. In this approach, the longitude and Greenwich Mean Time (GMT) for each profile are converted to local solar times. The bivariate library subroutine IBI is called to perform the interpolation, which can be either a first-order or second-order Lagrangian interpolation. However, before the interpolator can be called, a complete table (two-dimensional array) must be formed; the elements of this table are values of the function being interpolated at a given altitude. The diagonal elements are the values on the input meteorological profiles. The off-diagonal terms are obtained by translation from the diagonal terms using default latitude gradients, since the latitude gradients are more accurate than the diurnal/semidiurnal gradients. If first-order interpolation is used, a 2x2 table must be constructed. If second-order interpolation is used, then a 3x3 table (requiring three meteorological profiles) must be constructed. The governing equations for conventional two-dimensional Lagrangian interpolation are as follows:

$$Z = \sum_{i=0}^{m} \sum_{j=0}^{n} X_{m,i}(X_0)\, Y_{n,j}(Y_0)\, F(i,j) \qquad (4\text{-}74)$$

$$X_{m,i}(X_0) = \prod_{\substack{k=0 \\ k \neq i}}^{m} \frac{X_0 - X_k}{X_i - X_k} \qquad i = 0, 1, \cdots, m \qquad (4\text{-}75)$$

$$Y_{n,j}(Y_0) = \prod_{\substack{k=0 \\ k \neq j}}^{n} \frac{Y_0 - Y_k}{Y_j - Y_k} \qquad j = 0, 1, \cdots, n \qquad (4\text{-}76)$$

where m = order of interpolation in the X direction
n = order of interpolation in the Y direction
and F(I,J) is the value of the function at (X(I), Y(J)).

The values of the X and Y arrays must be in algebraically increasing order. For interpolation of meteorological data, the X array corresponds to latitude and the Y array corresponds to local solar time.

As indicated above, values from the meteorological profiles will normally form the diagonal of the bivariate function table. However, in certain cases, such as when the latitude of the middle profile (in ascending longitude) is greater than the latitude of the third profile, two rows or two columns must be interchanged in order to satisfy the requirement of algebraically increasing values of the two independent variables. The table can still be completed using the default latitude gradients, but the interpolated values may not be as accurate.

4.6 READJUSTMENT OF DIURNAL AND SEMIDIURNAL COEFFICIENTS AND LATITUDE GRADIENTS

It is possible to construct a revised set of amplitudes and phases for the diurnal and semidiurnal coefficients and a new set of latitude gradients of the atmospheric parameters, given meteorological data with a sufficient spread in latitude and local solar time. The readjustment procedure is as follows:

1. Interpolate the values of the observed parameters to the altitudes at which the default coefficients and gradients are tabulated.
2. Using the default diurnal and semidiurnal coefficients, translate the interpolated parameters to a reference local solar time.
3. Construct a new set of latitude gradients from the translated parameters.
4. Using the new latitude gradients, translate the original interpolated parameters to a reference latitude.
5. Construct a new set of diurnal and semidiurnal coefficients from the translated parameters. Steps 2 through 5 may be repeated.

In practice, the above procedure involves some difficulties. Some of the default translational coefficients are poorly known and may not be close enough to the actual values to yield good results. Even more important is the fact that a sufficient spread of data may not be available.

The currrent version of the LAIRS Program assumes that no more than three separate meteorological profiles are to be input to the system, and thus cannot solve for the entire set of five coefficients at each altitude level. Instead, only the diurnal and semidiurnal amplitudes and the latitude gradients are calculated, the phases remaining at their default values. No iteration is attempted. The user should be aware of how severely this process is limited by the quality and amount of available data and should use it only with the utmost care.

SECTION 5 - OPERATIONAL USE OF LAIRS

As stated in Section 1, the primary function of the LAIRS Program is to produce a set of atmospheric parameters for each point along the Shuttle reentry trajectory. In operational use, as soon as both the BET file, containing Shuttle positions as a function of time, and the meteorological data files are available, the LAIRS Program must output a single "best estimated atmosphere" covering the entire reentry path. This section describes the development of an optimal procedure for producing the best estimated atmosphere and makes recommendations for use of the LAIRS Program in an R&D environment.

5.1 LAIRS OPTIMAL PROCEDURE

The production of a single, smooth, continuous atmosphere giving the best fit to all the available data and simultaneously obeying the known laws of atmospheric physics over the entire range of the Shuttle reentry presents a number of challenges. The range covered by the Shuttle during reentry is quite large: over 200 kilometers in altitude, 50 degrees in latitude, and 120 degrees in longitude. The physical conditions and the quantity and quality of available meteorological data vary enormously over this range. Therefore, no single method can yield the best possible estimates of all atmospheric parameters along all portions of the reentry trajectory. However, it is possible to prescribe an "optimal" procedure that will produce a best overall atmosphere. This atmosphere can then serve as a baseline for investigators who may, if they wish, use LAIRS in different modes to study more fully particular regions of the atmosphere along the Shuttle reentry path.

5.1.1 SELECTION OF METEOROLOGICAL DATA

During the development phase of the LAIRS Program, it was expected that the meteorological data for operational use would be provided by NOAA in the form and format discussed in Section 2.1.2, i.e., up to three complete sets of vertical meteorological profiles would be provided. In actuality, the data available for the STS-1 studies consisted of several vertical profiles that were supplied by NOAA, NASA, and the Air Force, some of which contained only a partial set of atmospheric parameters. These vertical profiles were made at Barking Sands, Hawaii, and at Point Mugu, Wheeler Ridge, Tehachapi, and Edwards Air Force Base, California. All profile observations were made near the time of the Shuttle reentry. Since the LAIRS Program was designed to use a maximum of three files and since the Wheeler Ridge and Tehachapi profiles lacked density data, the Barking Sands, Wheeler Ridge, and Edwards profiles were chosen as the primary LAIRS input (subsequent investigations with the LAIRS differential correction process showed that the Wheeler Ridge and Tehachapi data yield results that are statistically equivalent to those obtained using the Edwards data). This data is discussed in more detail in Reference 8.

5.1.2 PRELIMINARY MODELING APPROACHES

The preliminary runs made with the LAIRS Program using this data used the straight interpolation model. Predictably, the results were quite rough, as shown in Figure 5-1. To produce a smoother fit, the Jacchia-Roberts model was used in the upper atmosphere and the polynomial (non-DC) fitting model was used in the lower atmosphere, with the temperature values calculated from the pressure and density values via the gas law.

The polynomial model requires the establishment of a reference profile as discussed in Section 4.2.2. It was

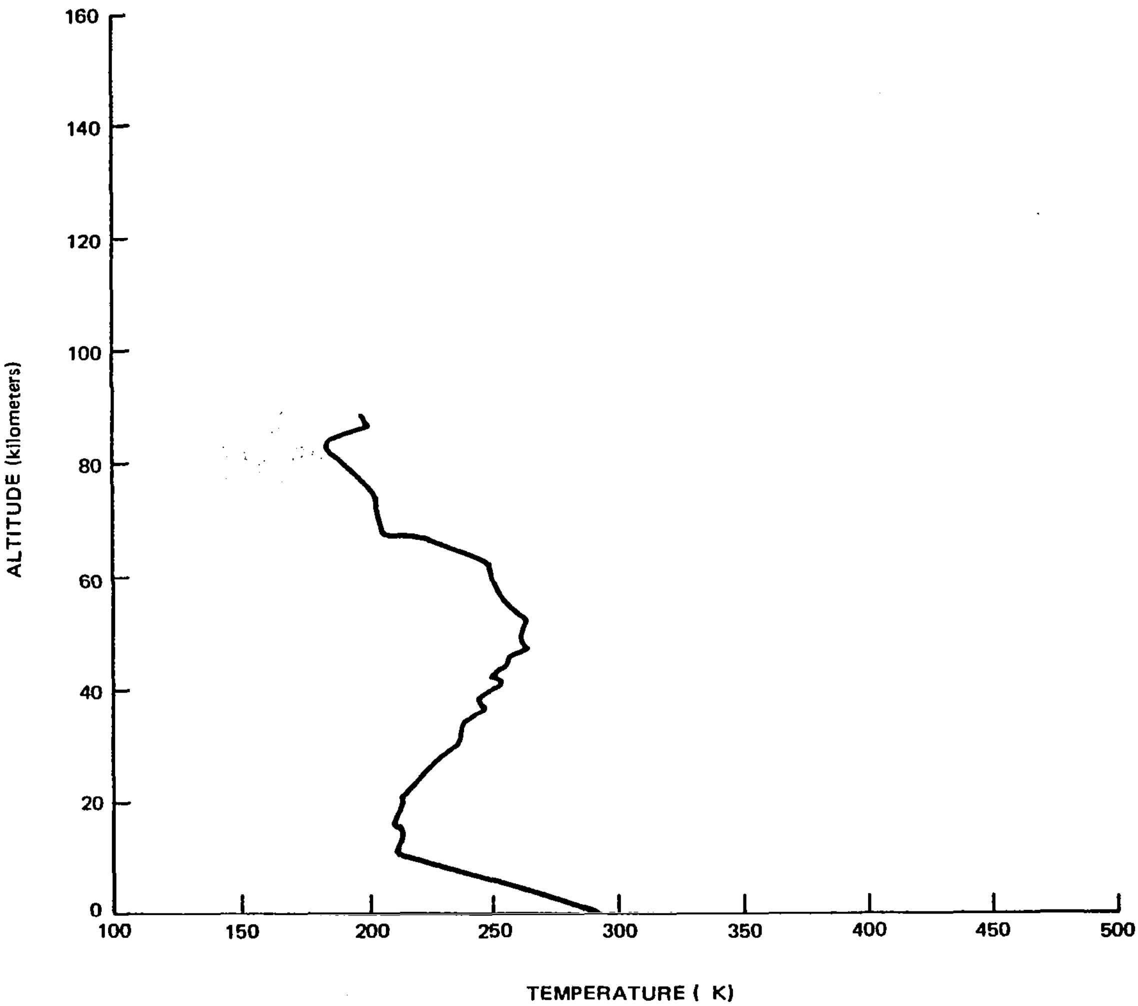

Figure 5-1. Interpolated Temperature Profile for STS-1

discovered that the location of the reference profile is of great importance in determining the smoothness of the estimated atmosphere because of the uncertainties in the diurnal and semidiurnal coefficients and in the latitude gradients. For example, when the reference profile is placed at Edwards Air Force Base at the time of Shuttle touchdown, the estimated atmosphere is somewhat rough in the vicinity of 90 kilometers. Moving the reference profile to Barking Sands produces a smooth curve in the upper part of the lower atmosphere, but it becomes somewhat rougher in the lower part. A compromise position for the reference profile may be used, but the fact that the parameters must first be translated from the meteorological file location to the reference location, then subjected to the fitting process, and then translated to the Shuttle position allows the uncertainties to propagate excessively when the total times and distances involved are large.

5.1.3 TWO-STEP MODELING APPROACH

To minimize the errors introduced in the translations and to ensure a smooth representation of the atmosphere, a revised procedure was developed which uses the LAIRS Program in a two-step mode. First, a LAIRS run is made using the interpolation model to yield unsmoothed values of the atmospheric parameters translated to the Shuttle trajectory. A new LAIRS routine outputs these parameters in the same format as a standard LAIRS meteorological file. In the second step, this new file, called USEMET, is input to a LAIRS polynomial model run with the latitude, diurnal, and semidiurnal corrections turned off.

This process, in effect, takes the Shuttle trajectory as the reference profile location. The result is a smooth set of parameters that are in agreement with the interpolated and translated data (see Figure 5-2). The number of points on

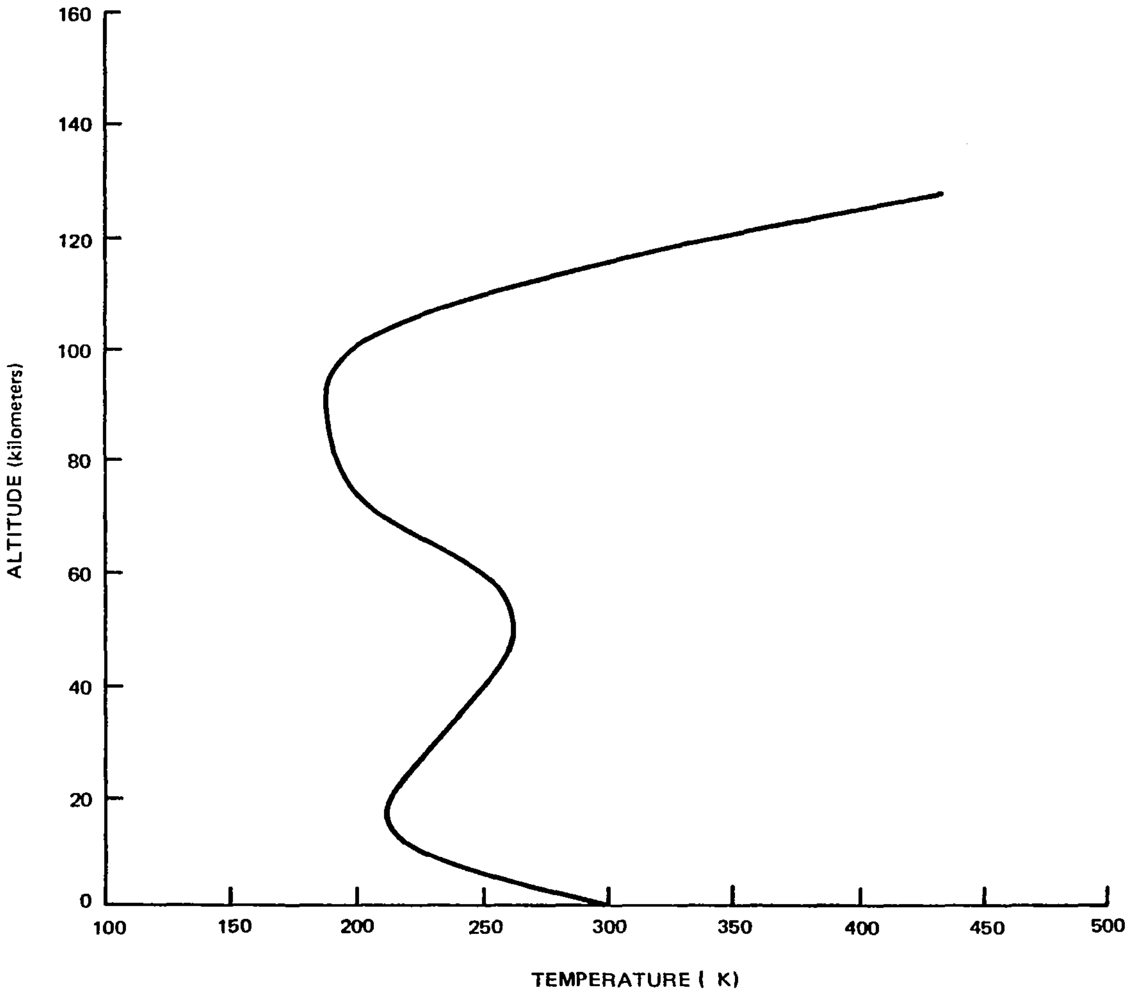

Figure 5-2. Fitted Temperature Profile for STS-1 (Merging Parameter = 5 Kilometers)

the USEMET file can be controlled by the interval field on the ENTREE card and can be set approximately equal to the original number of data points. The creation of the USEMET file is invoked by the keyword card CREATE.

5.1.4 MODEL REFINEMENTS

The parameters obtained using the above procedure still cannot be guaranteed to be the "best" set that can be produced. In the analysis of the STS-1 data, it was discovered that changing the atmospheric segment boundaries via the MODBOUND keyword card could substantially improve the polynomial fit. There is no formal procedure for setting these boundaries; the user must inspect the interpolated data (Figure 5-1) and experiment. For STS-1, boundaries of 90 kilometers, 68 kilometers, and 14 kilometers produced good results.

Another variable that can be adjusted is the merging interval at each segment boundary. This is the region around the boundary where the polynomial coefficients for the segments on both sides of the boundary are computed. For example, if the bottom segment boundary is 25 kilometers and the merging region is set at 5 kilometers, the meteorological data up to 30 kilometers is used in determining the polynomial coefficients for the bottom segment, and the data down to 20 kilometers is used in determining the coefficients for the middle segment. In the parameter calculations, however, the middle segment coefficients are used only down to 25 kilometers and the lower segment coefficients are used below 25 kilometers. This scheme was devised to reduce possible discontinuities in the derivatives of the parameters at the boundaries in a differential correction (DC) run (in a non-DC run, this approach is used to reduce the possibility of discontinuities in the parameters themselves). Thus, making the merging region too small can have undesirable effects. Figure 5-3 shows the results of a differential correction run with a merging parameter of 1 kilometer. The curve mimics the data reasonably well in most places and it is continuous, but it looks decidedly nonphysical. Experience with STS-1 suggests a merging factor of at least 3 or 4 kilometers (see Figure 5-2). The merging parameter is set on the MODBOUND keyword card.

In a differential correction run, several other parameters may be changed to alter the fit. These include the editing criteria and, when no measurement uncertainties are available, the relative a priori weights of the temperature, pressure, and density. These are controlled by the DCEDIT keyword card.

5.2 R&D USE OF LAIRS

LAIRS may be used in a variety of ways to improve the estimate of atmospheric parameters in any particular region of the atmosphere. If one is interested in only a small portion of the reentry trajectory, e.g., around 90 kilometers, the two-step approach described above becomes unnecessary, and the user may simply place the reference profile at the time and place of interest. Segment boundaries, editing criteria, weighting factors, etc., can be adjusted to give optimum results in the region under study as long as the fit in other regions is not critical.

With regard to determining the reliability of the estimated parameters, the following procedure may prove useful. First, a LAIRS default model run for the day of reentry will give the user an approximate knowledge of the values to be expected from the actual data. When the actual data becomes available, the "best estimated atmosphere" can be produced via the optimal procedure. This atmosphere can then be compared with the original data (bearing in mind that diurnal

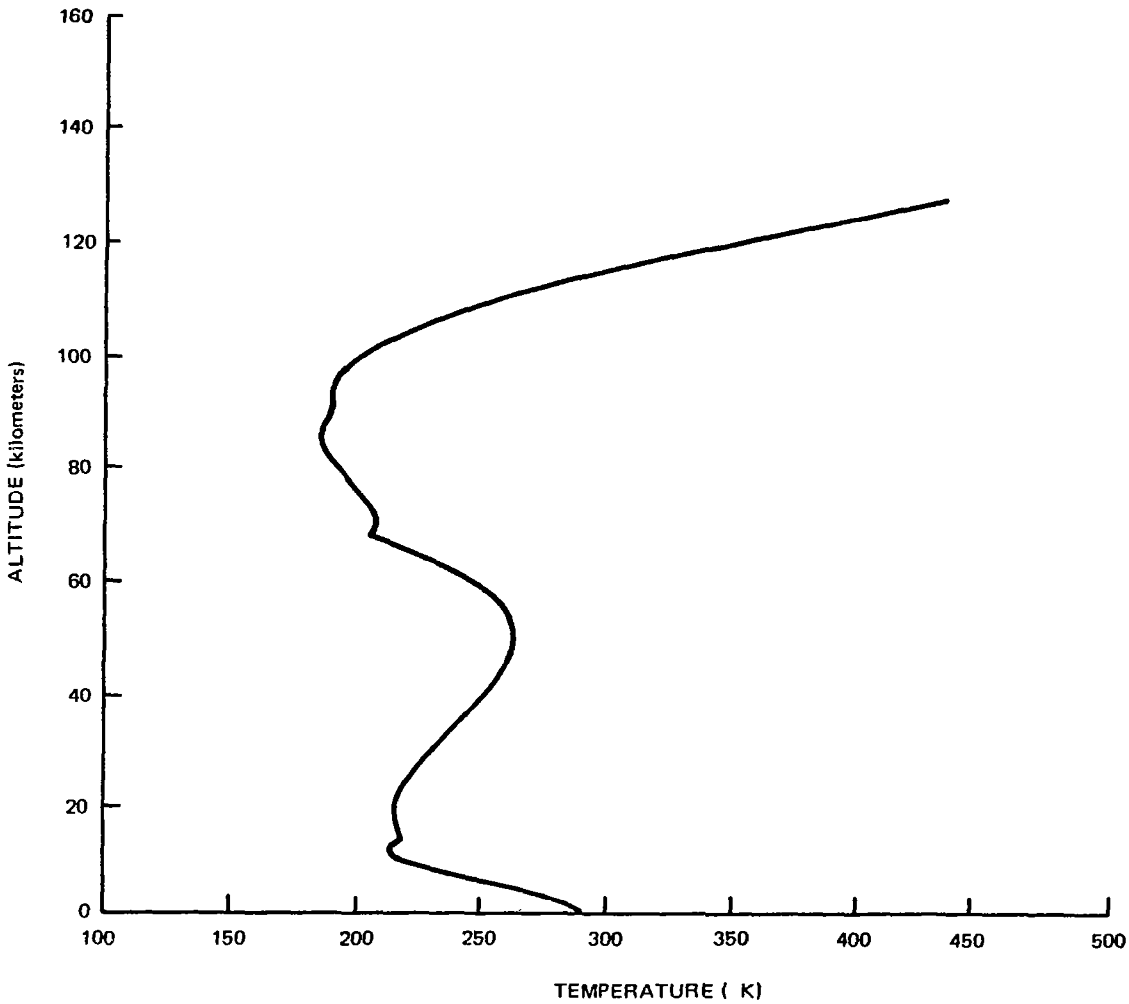

Figure 5-3. Fitted Temperature Profile for STS-1 (Merging Parameter = 1 Kilometer)

and latitudinal corrections have been made and that, in a differential correction run, all three parameters may be used to produce the values of any single parameter). The best estimated atmosphere should also be judged against the intermediate interpolated file used to create it. Finally, if onboard pressure measurements are available from the Shuttle, they can be compared with onboard pressure measurements estimated by LAIRS. This provides an independent check on the reliability of the calculated parameters.

APPENDIX A - COMMON BLOCK DESCRIPTIONS

This appendix contains descriptions of all COMMON blocks used in the LAIRS Program. The COMMON blocks are listed in alphabetical order.

BLOCK DATA CALCOM

COMMON BLOCK CALCOM

PURPOSE:
/CALCOM/ STORES ONE BLOCK OF SHUTTLE TRAJECTORY POINTS OR LAP POINTS AND THE ATMOSPHERIC PARAMETERS CALCULATED AT THOSE POINTS. ONE BLOCK = 10 POINTS.

REFERENCED BY: LAIRS,PARAMS,OUTPRF,LAP,ENTRD

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
TRJ	R	5,10	10 TRAJECTORY POINTS: ALTITUDE,LATITUDE,LONGITUDE,GMT, LOCAL SOLAR TIME
TPDW	R	7,10	10 PARAMETER SETS CORRESPONDIG TO THE TRAJECTORY POINTS. EACH SET CONTAINS: TEMPERATURE,PRESSURE,DENSITY, E-W WIND U, N-S WIND V, WIND WIND SPEED, AND WIND DIRECTION
UTRJ	R	5,10	UNCERTAINTIES IN THE TRAJECTORY COMPONENTS
UTPDW	R	7,10	UNCERTAINTIES IN THE CALCULATED PARAMETERS
WTMOL	R	10	MEAN MOLECULAR WEIGHTS
SCHT	R	10	PRESSURE SCALE HEIGHT (KM)
V(10)	R	10	SHUTTLE VELOCITIES (M/SEC)
ALPHA	R	10	SHUTTLE ANGLES OF ATTACK (DEG)
RMC	R	10	MACH NUMBERS
PNC	R	10	CALCULATED ONBOARD MEASUREMENTS
DEV	R	10	PERCENT DEVIATIONS FROM GAS LAW

TOTAL SIZE: 310 WORDS

PROGRAMMER: D. E. BOLAND, CSC

Block Data CALCOM

BLOCK DATA COFCOM

PURPOSE:

/COFCOM/ STORES POLYNOMIAL COEFFICIENTS AND MODEL STANDARD DEVIATIONS (UNCERTAINTIES) FOR TEMPERATURE, LOG PRESSURE, AND LOG DENSITY FOR EACH OF THE 3 ATMOSPHERIC SEGMENTS.

REFERENCED BY: LAIRS,POLFIT,POLCAL,OUTSUM,POLY

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
CT	R	3,4	4 TEMPERATURE COEFFICIENTS FOR EACH ATMOSPHERIC SEGMENT
CP	R	3,4	4 PRESSURE COEFFICIENTS FOR EACH ATMOSPHERIC SEGMENT
CD	R	3,4	4 DENSITY COEFFICIENTS FOR EACH ATMOSPHERIC SEGMENT
UT	R	3	TEMPERATURE STANDARD DEVIATION FOR EACH SEGMENT
UP	R	3	PRESSURE STANDARD DEVIATION FOR EACH SEGMENT
UD	R	3	DENSITY STANDARD DEVIATION FOR EACH SEGMENT
COVAT	R	3,5,5	COVARIANCE MATRIX FOR TEMPERATURE FOR EACH SEGMENT
COVAP	R	3,5,5	COVARIANCE MATRIX FOR PRESSURE FOR EACH SEGMENT (CURRENTLY DUMMY)
COVAD	R	3,5,5	COVARIANCE MATRIX FOR DENSITY FOR EACH SEGMENT (CURRENTLY DUMMY)

TOTAL SIZE: 270 WORDS

PROGRAMMER: D. E. BOLAND, CSC

Block Data COFCOM

```
    BLOCK DATA CONCOM

PURPOSE:
    /CONCOM/ STORES CONSTANTS NEEDED BY VARIOUS ROUTINES

REFERENCED BY: GWIND,DIGRAD,TRNDSD,DSDADJ,WCNVRT,HIALT,JACROB,JR

COMMON BLOCK PARAMETERS:
    NAME      TYPE   DIMENSION   DESCRIPTION
    PI         R         1        PI
    TWOPI      R         1        TWO TIMES PI
    DTR        R         1        DEGREES TO RADIANS CONVERSION
                                  FACTOR
    RTD        R         1        RADIANS TO DEGREES CONVERSION
                                  FACTOR
    HTD        R         1        HOURS TO DEGREES CONVERSION FACTOR
    ANG        R         1        ANGULAR VELOCITY OF EARTH
    R          R         1        RADIUS OF EARTH
    DUM        R         13       SPARES

TOTAL SIZE: 20 WORDS

PROGRAMMED BY: D. E. BOLAND, CSC
```

Block Data CONCOM

```
    BLOCK DATA DCCOM

COMMON BLOCK NAME: /DCCOM/

PURPOSE:
    /DCCOM/ STORES DC PROCESS CONTROL FLAGS READ IN THROUGH DC
    KEYWORD CARDS.

COMMON BLOCK PARAMETERS:
   NAME       TYPE   DIMENSION    DESCRIPTION
   MLDATA(N,L) I       (3,3)       METEOROLOGICAL DATA SELECTION FLAGS:
                                    =0, DO NOT INCLUDE L TYPE MET. DATA
                                    IN DC FOR SEGMENT N
                                    =1, INCLUDE
                                     L=1, TEMPERATURE
                                     L=2, PRESSURE
                                     L=3, DENSITY
   KSSEG(N)    I        3          CONTINUITY FLAGS:
                                    =0, CONTINUITY IS IMPOSED AT THE TOP
                                    BOUNDARY OF THE NTH SEGMENT
                                    =1, CONTINUITY IS NOT IMPOSED
   ISGM        I        1          DC SEGMENTATION FLAG:
                                    =0, NORMAL DC (CONTINUITY IMPOSED AT
                                    ALL BOUNDARIES)
                                    =1, SEGMENTWISE INDEPENDENT DC

   IDCSEG(N)   I        3          DC FLAG FOR EACH SEGMENT:
                                    =0, NO DC FOR THE NTH SEGMENT
                                    =1, DC FOR THE NTH SEGMENT
   WTDCT       R        3          A PRIORI WEIGHTING FOR TEMPERATURE
                                   FOR EACH SEGMENT (5% UNCERTAINTY)
   WTDCP       R        3          A PRIORI WEIGHTING FOR PRESSURE
                                   FOR EACH SEGMENT (5% UNCERTAINTY)
   WTDCD       R        3          A PRIORI WEIGHTING FOR DENSITY
                                   FOR EACH SEGMENT (5% UNCERTAINTY)
   ALFA        R        5          INTEGRANDS FOR PARTIAL DERIAVATIVES
                                   OF PRESSURE AND DENSITY
TOTAL SIZE: 30 WORDS

PROGRAMMER: T. LEE, CSC       JULY 1981
```

Block Data DCCOM

BLOCK DATA FILCOM

PURPOSE:
/FILCOM/ STORES THE LOGICAL UNIT NUMBERS OF VARIOUS FILES, AND STORES INFORMATION NEEDED BY THE OUTPUT ROUTINES. FILCOM IS ACCESSED BY VIRTUALLY ALL LAIRS ROUTINES.

REFERENCED BY:

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
NPRINT	I	1	PRINTED OUTPUT LUN
NREAD	I	1	CARD INPUT LUN
NUSE	I	1	USER FILE LUN
NPRM	I	1	PERMANENT FILE LUN
NWRK	I	1	WORKING FILE LUN
NENT	I	1	ENTREE FILE LUN
NKP	I	1	KP FILE LUN
NOIDS	I	1	COMMON BLOCK VALUES LUN
NUSMET	I	1	CREATED METEOROLOGICAL FILE LUN
NDUM	I	2	DUMMIES
MWRK1	I	1	METEOROLOGICAL FILE LUN
MWRK2	I	1	METEOROLOGICAL FILE LUN
MWRK3	I	1	METEOROLOGICAL FILE LUN
NDUM2	I	8	DUMMIES
NITER	I	1	ITERATION COUNTER FOR DC OUTPUT
LINES	I	1	LINE COUNTER
IPAGE	I	1	PAGE COUNTER

TOTAL SIZE: 25 WORDS

PROGRAMMER: D. E. BOLAND, CSC

Block Data FILCOM

BLOCK DATA INTCOM

PURPOSE:
/INTCOM/ STORES VALUES RETRIEVED FROM THE WORKING FILE BY DFLINT.

REFERENCED BY: LAIRS,DFLINT,METINT,POLY,SETREF,WIND,POLADJ,
METREF,TRNADJ

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
IPT	I	1	INTERPOLATION POINTER (LAST POINT REFERENCED)
IPTFLG	I	1	FLAG FOR FIRST CALL TO DFLINT
ALT	R	6	BLOCK OF RETRIEVED ALTITUDES
TPDWAR	R	6,5	BLOCK OF RETRIEVED PARAMETERS: T,P,D,U,V
ARR	R	6,27	ALL OTHER VALUES RETRIEVED FROM WORKING FILE (SAME ORDER AS ON FILE)

TOTAL SIZE: 260 WORDS

PROGRAMMER: R. A. KUSESKI, CSC.

Block Data INTCOM

```
      BLOCK DATA JRCOM

      COMMON/JRCOM / PHJ       ,HCJ      ,TINF     ,TX       ,DNHE     ,
     *               CM(6)     ,CF       ,DD(5,7)  ,ADT(6)   ,ZJX      ,
     *               AVG       ,RCM      ,T0       ,RC       ,GLO      ,
     *               ZJ0       ,FKL      ,TZ       ,TCIL     ,RL1      ,
     *               DUM1      ,RL2      ,DUM2     ,XLPS     ,YLPS     ,
     *               UC(2)     ,WC(2)    ,XCDI     ,VCDI     ,FLC4     ,
     *               CC(5)     ,ZD(7)    ,SD(5)    ,CMZ      ,
     *               RHOZ      ,AD(6)    ,BD(6)    ,AC(7)
     *              ,CFL(5)    ,HGT      ,DPJDT    ,FITPRM(4)

C    MASSES OF THE ATMOSPHERIC CONSTITUENTS IN GM/MOLE.

      DATA   CM        /28.013400,39.94800 ,4.002600 ,31.998800,15.999400,
     *                  1.0079700/

C    CORRECTION FACTOR IN KM

      DATA   CF        /11825.00 /

C    POWER SERIES COEFFICIENTS FOR COMPUTING RHOS AT INFLECTION POINT
C    (NO LONGER USED.  SEE SUBROUTINE MODADJ DESCRIPTION.)

      DATA   DD         /0.1093155E2         ,0.8049405E1         ,
     *                    .7646886E1         , .9924237E1         ,
     *                    .1097083E2         , .1186783E-2        ,
     *                    .2382822E-2        ,-.4383486E-3        ,
     *                    .1600311E-2        , .6118742E-4        ,
     *                   -.1677341E-5        ,-.3391366E-5        ,
     *                    .4694319E-6        ,-.2274761E-5        ,
     *                   -.1165003E-6        , .1420228E-8        ,
     *                    .2909714E-8        ,-.2894886E-9        ,
     *                    .1938454E-8        , .9239354E-10       ,
     *                   -.7139785E-12       ,-.1481702E-11       ,
     *                    .9451989E-13       ,-.9782183E-12       ,
     *                   -.3490739E-13       , .1969715E-15       ,
     *                    .4127600E-15       ,-.1225838E-16       ,
     *                    .2698450E-15       , .5116298E-17       ,
     *                   -.2296182E-19       ,-.4837461E-19       ,0.00     ,
     *                   -.3131808E-19       ,0.00                /

C    THERMAL DIFFUSION COEFFICIENTS

      DATA   ADT       /2*0.00    ,-.3800    ,3*0.00    /

C    INFLECTION POINT HEIGHT IN KM

      DATA ZJX         /125.00/
```

Block Data JRCOM (1 of 3)

```
AVOGADRO'S NUMBER IN NUMBER / MOLE
  DATA AVG       /6.02257E23/
AVERAGE EARTH RADIUS IN KM
  DATA RCM       /6356.76600/
TEMPERATURE AT MINIMUM HEIGHT IN DEGREES KELVIN
  DATA TO        /183.00/
UNIVERSAL GAS CONSTANT IN JOULES/DEGREE KELVIN/MOLE
  DATA   RC      /8.3143200/
MEAN SURFACE GRAVITY IN M/SEC**2
  DATA  GLO      /9.80665000/
MINIMUM HEIGHT IN KM
  DATA ZJO       /90.00/
INITIAL APPROXIMATIONS TO RL1,RL2,XLPS,YLPS
  DATA   RL1,RL2,XLPS,YLPS /166.00   ,61.00    ,99.00    ,28.00    /
POWER SERIES COEFFICIENTS FOR TZ
  DATA  CC       /-.8928437500E8     ,.35424E7 ,-.526875E5          ,
 *               .3405E3   ,-.800    /
POWER SERIES COEFFICIENTS FOR RHO(100)/MO
  DATA   ZD      /.1985549E-10       ,-.1833490E-14      ,
 *                .1711735E-17       ,-.1021474E-20      ,
 *                .3727894E-24       ,-.7734110E-28      ,
 *                .7026942E-32       /
COEFFICIENTS FOR COMPUTING NUMBER DENSITY AT Z=100KM
  DATA  SD       /.7811000 ,.93432E-2,.61471E-5,.16177800,.09554400/
MEAN MOLECULAR MASS AT SEA LEVEL IN GM/MOLE
  DATA CMZ       /28.96000 /
```

Block Data JRCOM (2 of 3)

```
ATMOSPHERIC DENSITY AT Z=90 KM IN GM/CM**3

  DATA RHOZ      /3.46E-9/

CONSTANT COEFFICIENTS FOR THE B(N) SERIES

  DATA    AD      /.3144902516672729E10
 *                -.1237748854832917E9,.1816141096520398E7,
 *                -.1140331079489267E5,.2436498612105595E2,
 *                .8957502869707995E-2/

LINEAR COEFFICIENTS FOR THE B(N) SERIES

  DATA    BD      /-.5286448217910969E8,
 *                -.1663250847336828E5,-.1308252378125E1   ,
 *                3*0.00                /

MOLECULAR POWER SERIES COEFFICIENTS

  DATA    AC      /-.435093363387E6    ,.282755646391E5    ,
 *                -.765334661080E3     ,.110433875450E2    ,
 *                -.8958790995E-1      ,.38737586E-3       ,
 *                -.697444E-6          /

COEFFICIENTS FOR COMPUTING CF

  DATA    CFL     /.1031445E5          ,.2341230E1         ,
 *                .1579202E-2          ,-.1252487E-5       ,
 *                .2462708E-9          /
  END
```

Block Data JRCOM (3 of 3)

BLOCK DATA METCOM

PURPOSE:
/METCOM/ STORES VALUES FROM METEOROLOGICAL PROFILES USED FOR METEOROLOGICAL INTERPOLATION.

REFERENCED BY: LAIRS,METINT,METIN1,TRNADJ,SETREF

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
IPT	I	1	POINTER USED IN LIBRARY ROUTINE IUNI
METFLG	I	1	FLAG FOR FIRST CALL TO METIN1
II	I	1	POINTER TO CLOSEST ALTITUDE IN TRAJECTORY ARRAY
ALTM	R	3,6	ARRAY OF ALT. FOR EACH PROFILE
METARR	R	3,6,10	ARRAY OF T,P,D AND WIND SPEED AND DIRECTION FOR EACH PROFILE
FSTPT	R	3	LOWEST ALT. FOR EACH PROFILE
RLAT	R	3	LATITUDE OF EACH PROFILE
RLONG	R	3	LONGITUDE OF EACH PROFILE
RLSTM	R	3	LOCAL SOLAR TIME FOR EACH PROFILE

TOTAL SIZE: 240 WORDS

PROGRAMMER: R.A. KUSESKI, COMPUTER SCIENCES CORP.

Block Data METCOM

BLOCK DATA SOLAND

PURPOSE:
/SOLAND/ STORES DIFFERENTIAL CORRECTION CONTROL PARAMETERS AND STATISTICS

REFERENCED BY: NLSPOL,SOLVE,GRAND,DPAR,TPAR,PPAR

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
IMAX	I	1	MAX. NUMBER OF INTEGRALS FOR SIMP
KS4	I	1	FLAG FOR BOUNDARY TEMPERATURE SOLVE-FOR
KS5	I	1	FLAG FOR BOUNDARY PRESSURE SOLVE-FOR
NPOL	I	1	ORDER OF TEMP. POLYNOMIAL
MAXSOL	I	1	MAX. NUMBER OF SOLVE-FOR PARAMETERS
NSOL	I	1	ACTUAL NUMBER OF SOLVE-FOR PARAMETERS
KEDTOT	I	1	TOTAL NUMBER OF MET. DATA USED
KONVRG	I	1	CONVERGENCE FLAG
IDUM	I	2	SPARES
ZREF	R	1	REFERENCE ALTITUDE
EPSLON	R	1	CONVERGENCE TOLERANCE CRITERIA
SRSUM	R	1	SUM OF SQUARED WEIGHTED RESIDUALS
CURRMS	R	1	CURRENT WEIGHTED RMS
OLDRMS	R	1	PREVIOUS WEIGHTED RMS
RMSP	R	1	PREDICTED RMS
A	R	10	SOLVE-FOR PARAMETER ARRAY
G	R	10	RIGHT HAND SIDE OF NORMAL EQUATION
SH	R	55	LINEAR ARRAY OF UPPER TRIANGULAR PART OF NORMAL MATRIX
RDUM	R	9	SPARES

PROGRAMMER: T. LEE CSC MARCH 1981

Block Data SOLAND

```
    BLOCK DATA TKPTC
COMMON BLOCK NAME: /TKPTC/

PURPOSE:
    /TKPTC/ INITIALIZE VALUES FOR THE KP FILE

REFERENCED BY: LAIRS,JACCWF,JACROB

COMMON    BLOCK   PARAMETERS:
 NAME      TYPE    DIMENSION          DESCRIPTION
 IT         I        1                TIME OF FIRST DAY OF TC DATA
                                      IN COMMON
 KP         I        21,8             MAGNETIC ACTIVITY 3-HOUR INDICES
 TC         R        20               EXOSPHERIC TEMPERATURE

TOTAL SIZE:  189 WORDS

PROGRAMMER ANALYST:  A. K. KAPOOR, COMPUTER SCIENCES CORPORATION
```

Block Data TKPTC

BLOCK DATA USECOM

COMMON BLOCK NAME: /USECOM/

PURPOSE:
/USECOM/ STORES THE DATA INPUT BY THE USER ON KEYWORD CARDS. USECOM IS ACCESSED BY VIRTUALLY ALL LAIRS ROUTINES.

COMMON BLOCK PARAMETERS:

NAME	TYPE	DIMENSION	DESCRIPTION
IPRFL	I	1	TYPE OF PROFILE: =1, ENTREE =2, LAP
MODL	I	1	TYPE OF LOWER ATMOSPHERIC MODEL: =1, DEFAULT INTERPOLATION =2, METEOROLOGICAL INTERPOLATION =3, DEFAULT POLYNOMIAL =4, ADJUSTED POLYNOMIAL
IWL	I	1	TYPE OF L.A. WIND MODEL: =0, NO WIND =1, EMPIRICAL (INTERPOLATED) WIND =2, ANALYTIC WIND
ILATL	I	1	LATITUDE VARIATIONS IN L.A.: =0, DO NOT INCLUDE =1, INCLUDE
IDSDL	I	1	DIURNAL/SEMIDIURNAL VARIATIONS, L.A. =0, DO NOT INCLUDE =1,INCLUDE
MODU	I	1	TYPE OF UPPER ATMOSHPHERIC MODEL: =1, DEFAULT INTERPOLATION =2, METEOROLOGOCAL INTERPOLATION =3, DEFAULT JACCHIA-ROBERTS
IWU	I	1	TYPE OF U.A. WIND MODEL =0, NO WIND =1, EMPIRICAL (INTERPOLATED) WIND
ILATU	I	1	LATITUDE VARIATIONS IN U.A. =0, DO NOT INCLUDE, EXCEPT IN JR =1, INCLUDE
IDSDU	I	1	DIURNAL/SEMIDIURNAL VARIATIONS, U.A. =0, DO NOT INCLUDE, EXCEPT IN JR =1, INCLUDE
IDRV	I	1	DERIVE PRESSURE AND DENSITY FROM TEMPERATURE VIA PHYSICAL LAWS (OVERRIDES ALL OTHER SELECTIONS)
INTP	I	1	ALTITUDE INTERPOLATOR TYPE: =1, FIRST ORDER LAGRANGE =2, SECOND ORDER LAGRANGE

Block Data USECOM (1 of 3)

IDBG	I	1	PRINT DEBUG: =0, NO =1, YES
INT	I	1	HORIZONTAL INTERPOLATOR TYPE: =0, UNIVARIATE =1, FIRST ORDER BIVARIATE =2, SECOND ORDER BIVARIATE
IDNUM	I	1	ENTREE-LAP ID NUMBER
IGAS	I	1	GAS LAW CALCULATION OVERRIDE
NSAMP	I	1	ENTREE FILE SAMPLING INTERVAL(POINTS)
ITER	I	1	MAXIMUM NUMBER OF ITERATIONS
IWT	I	1	INCLUDE WEIGHTING: =0, NO =1, YES
IDSDA	I	1	ADJUST D/SD COEFFICIENTS: =0, NO =1, YES
ILATA	I	1	ADJUST LATITUDE GRADIENTS: =0, NO =1, YES
IDC	I	1	PERFORM DIFFERENTIAL CORRECTIONS: =0, NO =1, YES
ITDAT	I	1	INCLUDE TEMPERATURE DATA IN DC: =0, NO =1, YES
IPDAT	I	1	INCLUDE PRESSURE DATA IN DC: =0, NO =1, YES
IDDAT	I	1	INCLUDE DENSITY DATA IN DC: =0, NO =1, YES
IDMY	I	1	DUMMY
NFIL	I	1	NUMBER OF METEOROLOGICAL FILES
KWRITE	I	1	FULL OUTPUT PRINT FLAG
ICRT	I	1	FLAG FOR CREATION OF NEW METEOROLOGICAL FILE FROM USER FILE
IDUM	I	2	SPARES
YMD	R	1	YEAR, MONTH, DAY OF LAP OR ENTREE TRAJECTORY
HMS	R	1	HOURS, MINUTES, SECONDS OF FIRST POINT ON ENTREE TRAJECTORY
THETA	R	1	LATITUDE OF LAP
TAU	R	1	LOCAL SOLAR TIME OF LAP
Z1	R	1	LOWER PROFILE ALTITUDE
Z2	R	1	UPPER PROFILE ALTITUDE

Block Data USECOM (2 of 3)

ZDUM	R	6	DUMMIES
BOUND	R	3	BOUNDARIES BETWEEN 4 SEGMENTS: 90KM, 65KM, 25KM
HMSSEC	R	1	ENTREE FILE HMS START TIME IN DECIMAL SECONDS
ZREF	R	1	REFERENCE ALTITUDE (KM) FOR DERIVATION OF P AND D
PREF	R	1	PRESSURE AT ZREF
STEP	R	1	INTEGRATION STEPSIZE (KM)
CONV	R	1	CONVERGENCE CRITERION FOR DC
RMERGE	R	1	REGION FOR POLYNOMIAL MERGING ON EACH SIDE OF SEGMENT BOUNDARIES (KM)
REFLAT	R	1	MODEL REFERENCE LATITUDE
REFTAU	R	1	MODEL REFERENCE LOCAL SOLAR TIME
RMGMT	R	3	GMT OF METEOROLOGICAL FILES
DUM	R	16	SPARES

TOTAL SIZE: 70 WORDS

Block Data USECOM (3 of 3)

APPENDIX B - FILE DESCRIPTIONS

This appendix specifies the formats of the files that are created and used by the LAIRS Program. Detailed descriptions of the working file, the user file, and the permanent file are presented in this appendix.

WORKING FILE

The working file is an indexed sequential file that stores the default atmospheric profile for the day of the Shuttle reentry or the local atmospheric profile. Each record is 38 words in length and there is one record per altitude level. The number of records depends on the altitude interval at which the default data has been tabulated; tabulation at each 5 kilometers up to 110 kilometers results in 23 records. Up to 50 records are allowed. The record format is the same as that of the permanent file.

USER FILE

The user file is a sequential file containing the calculated atmospheric parameters for each point on a local atmospheric profile or Shuttle trajectory. There is a title record describing the file, a header record, and one record for each altitude level at which the parameters were calculated. Each record contains 29 words.

The format of the title record is as follows:

Variable	Type	Dimension	Description
TITLE	A	8	Description of the file

The format of the header record is as follows:

Variable	Type	Dimension	Description
ID	I	1	ENTREE-LAIRS ID Number
DATE	R	1	YYMMDD. of LAP or ENTREE Trajectory
TIME0	R	1	HHMMSS.SS (GMT) of first point on ENTREE file
NSPR	R	1	Spare

The format of the data record is as follows:

Variable	Type	Dimension	Description
Z	R	1	Altitude (km)
THETA	R	1	Latitude (decimal degrees)
PHI	R	1	Longitude (decimal degrees)
GMT	R	1	Time (HHMMSS.SSSS)
TAU	R	1	Local solar time (HHMMSS.SSSS)

Variable	Type	Dimension	Description
T	R	1	Temperature (K)
P	R	1	Pressure (n/m^2)
D	R	1	Density (kg/m^3)
U	R	1	E-W wind component (m/sec)
V	R	1	N-S wind component (m/sec)
WS	R	1	Wind speed (m/sec)
WD	R	1	Wind direction (degrees from N, positive clockwise)
TU	R	1	Temperature uncertainty (K)
PU	R	1	Pressure uncertainty (n/m^2)
DU	R	1	Density uncertainty (kg/m^3)
UU	R	1	U uncertainty (m/sec)
VU	R	1	V uncertainty (m/sec)
WSU	R	1	WS uncertainty (m/sec)
WDU	R	1	WD uncertainty (degrees)
ZU	R	1	Altitude uncertainty (km)
THETAU	R	1	Latitude uncertainty (degrees)
PHIU	R	1	Longitude uncertainty (degrees)
GMTU	R	1	Time uncertainty (blank)
LSTU	R	1	Local solar time uncertainty (blank)

MWT	R	1	Mean molecular weight (g/mole)
SCHT	R	1	Pressure scale height (km)
M	R	1	Mach number
PN	R	1	Estimated onboard pressure measurement (n/m^2)
PCDEV	R	1	Percent gas law deviation

PERMANENT FILE

The permanent file is a sequential file that stores the default atmospheric profile for each month of the year. There are 12 sets of records, one record per altitude level, containing atmospheric parameters for each month. There are 38 words per record, including spares. To uniquely distinguish each record by month and by altitude, the record identification key is a floating-point number, the whole part of which is the number of the month and the decimal part of which is the altitude, e.g.,

1.025 = record for altitude of 25 kilometers in January
10.105 = record for altitude of 105 kilometers in October

The format of the header record is as follows:

Variable	Type	Dimension	Description
KEY	R	1	Header identification keyword
NREC	I	1	Total number of records in the file
NJAN	I	1	Number of records for January

Variable	Type	Dimension	Description
NFEB	I	1	Number of records for February
NMAR	I	1	Number of records for March
NAPR	I	1	Number of records for April
NMAY	I	1	Number of records for May
NJUN	I	1	Number of records for June
NJUL	I	1	Number of records for July
NAUG	I	1	Number of records for August
NSEP	I	1	Number of records for September
NOCT	I	1	Number of records for October
NNOV	I	1	Number of records for November
NDEC	I	1	Number of records for December
SPARES	R	25	Spares

The format of the data records is as follows:

Variable	Type	Dimension	Description
KEY	R	1	Month (1,2,...) + Z (km x 10^{-3})
THETA	R	1	Latitude (decimal degrees)
TAU	R	1	Local solar time (HHMMSS.SSSS)

Variable	Type	Dimension	Description
T	R	1	Temperature (K)
P	R	1	Pressure (n/m^2)
D	R	1	Density (kg/m^3)
U	R	1	E-W wind component (m/sec, positive east)
V	R	1	N-S wind component (m/sec, positive north)
DTLAT	R	1	Latitude temperature gradient (K/degree latitude)
DPLAT	R	1	Latitude pressure gradient (n/m^2/degree latitude)
DDLAT	R	1	Latitude density gradient (kg/m^3/degree latitude)
DULAT*	R	1	Latitude U gradient (m/sec/degree latitude)
DVLAT*	R	1	Latitude V gradient (m/sec/degree latitude)
DAT	R	1	Diurnal temperature amplitude (K)
DPT	R	1	Diurnal temperature phase (hours)
SDAT	R	1	Semidiurnal temperature amplitude (K)

*Latitude and diurnal/semidiurnal coefficients for winds (U and V) are not presently included on the file. The value "-9999." fills these locations. Below 25 kilometers, latitude and diurnal/semidiurnal coefficients are not presently included for any parameters. The value "-9999." fills these locations.

Variable	Type	Dimension	Description
SDPT	R	1	Semidiurnal temperature phase (hours)
DAP	R	1	Diurnal P amplitude (n/m^2)
DPP	R	1	Diurnal P phase (hours)
SDAP	R	1	Semidiurnal P amplitude (n/m^2)
SDPP	R	1	Semidiurnal P phase (hours)
DAD	R	1	Diurnal D amplitude (kg/m^3)
DPD	R	1	Diurnal D phase (hours)
SDAD	R	1	Semidiurnal D amplitude (kg/m^3)
SDPD	R	1	Semidiurnal D phase (hours)
DAU*	R	1	Diurnal U amplitude (m/sec)
DPU*	R	1	Diurnal U phase (hours)
SDAU*	R	1	Semidiurnal U amplitude (m/sec)
SDPU*	R	1	Semidiurnal U phase (hours)
DAV*	R	1	Diurnal V amplitude (m/sec)
DPV*	R	1	Diurnal V phase (hours)
SDAV*	R	1	Semidiurnal V amplitude (m/sec)
SDPV*	R	1	Semidiurnal V phase (hours)
SPARES	R	5	Spares

*See footnote on page B-7.

METEOROLOGICAL FILES (MET1, MET2, MET3)

The meteorological files are sequential files containing observed atmospheric parameters versus altitude. As there will be a maximum of three meteorological profiles obtained per Shuttle flight, only three meteorological data files have been created, MET1, MET2, and MET3.

Each file has a header record that contains the following information: total number of points for all the profiles, the number of profiles, the number of points for this profile, the number of points between 95 kilometers and 65 kilometers, the number of points between 65 kilometers and 25 kilometers, the number of points between 25 kilometers and 0 kilometers, the lowest altitude, the highest altitude, the latitude corresponding to the first point, and the longitude corresponding to the first point. There is one data record for each altitude level at which the atmospheric parameters are observed. All the parameters are in mks units and the altitude is in kilometers. The MET1, MET2, and MET3 files start at the highest altitude and go to their lowest altitude. The program PREMET sets up these files. File MET1 is written to unit 21, MET2 is written to unit 22, and MET3 is written to unit 23.

The input meteorological tape has to be of a certain format; otherwise the routine PREMET may have to be modified. Currently, the input tape has to have a header record that contains ten card images of 80 characters each (20A4). The data should then follow in units described in Reference 1.

PREMET is designed to be executed as a preprocessor routine that is independent of the LAIRS Program. PREMET could be modified to execute a meteorological tape having fewer or more header records but the output from PREMET may not be altered without altering the LAIRS Program.

The format of the header record for the meteorological files is as follows:

Variable	Type	Dimension	Description
IMET*	I	1	Total number of data points for n meteorological profiles; n = 1, 2, or 3.
NPRO*	I	1	Total number of profiles n for this data; n = 1, 2, or 3.
NUMPTS*	I	1	Total number of points for this profile.
ININTY*	I	1	Number of points between 95 and 65 kilometers for this profile.
IMIDLE*	I	1	Number of points between 65 and 25 kilometers for this profile.
ILOW*	I	1	Number of points between 25 and 0 kilometers for this profile.
RFRST	R	1	The lowest altitude for this profile.
RLAST	R	1	The highest altitude for this profile.
RLAT1	R	1	Latitude corresponding to point RFRST and used for this profile.
RLON1	R	1	Longitude corresponding to point RFRST and used for this profile.

*This is not essential information.

The format of the data record is as follows:

Variable	Type	Dimension	Description
RLAT	R	1	Latitude (degrees north)
RLON	R	1	Longitude (degrees east)
ALT	R	1	Altitude (km)
U	R	1	E-W wind component (m/sec, positive east)
V	R	1	N-S wind component (m/sec, positive north)
TE	R	1	Ambient temperature (K)
PR	R	1	Ambient pressure (n/m^2)
D	R	1	Ambient density (kg/m^3)
TEU	R	1	Ambient temperature systematic uncertainty (K)
PRU	R	1	Ambient pressure systematic uncertainty (n/m^2)
DU	R	1	Ambient density systematic uncertainty (kg/m^3)
UU	R	1	U uncertainty systematic uncertainty (m/sec)
VU	R	1	V uncertainty systematic uncertainty (degrees)

A sample job setup that can be executed to generate the meteorological files is shown below.

```
/JOB
LAIRS,T200,CM120000.                         1251JMP    PRICE
USER,XXXXXXX.
CHARGE,XXXXXX,LRC.
GET,PREMET.
FTN,R=3,B=OBPRE,I=PREMET.
LABEL,TAPE1,VSN=ST1412,LB=KU,D=800,F=S.
FILE,TAPE1,RT=F,MBL=80.
LDSET,FILES=TAPE1,PRESETA=NGINF,MAP=SBEX.
LOAD,OBPRE.
OBPRE.
REWIND,OUT1,MET1,MET2,MET3.
COPY,OUT1.
COPY,MET1.
COPY,MET2.
COPY,MET3.
REPLACE,OUT1,MET1,MET2,MET3.
DAYFILE,DAYFX.
REPLACE,DAYFX.
EXIT.
REWIND,OUT1,MET1,MET2,MET3.
COPY,OUT1.
COPY,MET1.
COPY,MET2.
COPY,MET3.
REPLACE,OUT1,MET1,MET2,MET3.
DAYFILE,DAYFX.
REPLACE,DAYFX.
/
```

GEOMAGNETIC INDICES FILE (KP)

A geomagnetic planetary indices file (KP) is required for the Jacchia-Roberts model in LAIRS. This file contains eight K_p values per day taken at 3-hour intervals. It also contains the daily solar flux number. Three LAIRS routines were developed to generate this file for a period of 1 year.

Program JRKP generates the K_p file (KP). The required K_p and solar flux data is obtained from the technical journal entitled, "Solar Geophysical Data Prompt Reports," which is issued monthly. The input data for Program JRKP must be in the following format:

Card 1

Columns	Format	Description
1-6	I6	Total number of input data cards.

Card 2 through n

Columns	Format	Description
1-6	I6	Date, YYMMDD., corresponding to the solar flux and K_p values.
8-12	F5.1	Flux number
14-38	8(I1,A2)	Eight K_p values with their signs.

Routine JRREAD was developed to read the KP file and dump it for inspection. It lists the K_p values in the processed format, not in their raw format.

A sample deck set-up is shown below to execute either of these options. When a new K_p file is to be generated, the user has to execute Program JRKP with a full year's worth of data. This restriction exists because of dimension statements in the coding.

To create the K_p file (KP)

```
GET,JRKP,KPDATA.
FTN,R=3,I=JRKP.
LGØ
REWIND,KP.
REPLACE,KP.
```

To dump the contents of the K_p file

```
GET,JRREAD,KP.
FTN,K=JRREAD,L=O,TS,B=ØBJRAD.
LØAD,ØBJRAD.
```

KPDATA is a file consisting of card images in the described format, containing the raw K_p and solar flux data. KP is a direct access file containing this data in a form suitable for use in the LAIRS Program.

APPENDIX C - LAIRS BENCHMARK DECKS

Figure C-1 shows a set of LAIRS keyword card decks used as benchmark tests during LAIRS development. These decks are set up for a LAIRS stacked deck run and illustrate the cards that exercise the various LAIRS options. Each deck begins with an ENTREE card and ends with an END card. The decks are processed in sequence until the FIN card is reached.

The first deck calls for each twentieth point on the input ENTREE file to be processed. The Jacchia-Roberts model is used in the upper atmosphere, and default interpolation (i.e., interpolation from the working file) is used in the lower atmosphere. Default interpolation is used for winds in both regions. Latitude variations and diurnal/semidiurnal effects are selected for the lower atmosphere (they are automatically included in the Jacchia-Roberts model). The interpolator type is second-order Lagrangian univariate in altitude.

The second deck is similar to the first, except that interpolation from meteorological files has been selected as the model to be used in the lower atmosphere (and for wind in both atmospheric segments). The two STATION cards indicate that two meteorological files are to be used. The first STATION card, which corresponds to the file input on tape 21, is labelled with a GMT of 8.0 hours. The second STATION card, corresponding to the file on tape 22, has a GMT of 11.0 hours. The altitude interpolator type is second-order Lagrangian univariate, and the horizontal interpolator type is first-order Lagrangian bivariate. The horizontal interpolation eliminates the need to specify latitude and diurnal/semi-diurnal corrections on the LOWMOD card.

The third deck calls for the polynomial model to be used in the lower atmosphere. In the simple linear mode selected in this deck, temperature, pressure, and density measurements will be independently fitted by separate polynomials.

The fourth deck is a duplicate of the third, except that pressure and density calculations will be performed by an integration of temperature at every ENTREE point processed. The reference value of pressure needed for this integration will be interpolated from the meteorological files at 30 kilometers altitude. The integration step size will be 0.5 kilometers.

The final deck calls for a nonlinear differential correction fit. All three data types (temperature, pressure, and density) will be used in this fit, although only the temperature polynomial coefficients will be produced. Calculation of pressure and density at each ENTREE point will proceed via integration, as was the case for the fourth deck. However, no DERIVE card needs to be included, as the values needed for integration will be set by the polynomial fitting routines.

Figure C-2 shows an example of a deck using the Local Atmospheric Profile (LAP) option, which will produce a vertical test profile of temperature, pressure, density, and winds. The date of the profile is April 12, 1980, at 10 hours, 0 minutes, 0 seconds GMT. The profile will be produced at latitude 35 degrees north and longitude 220 degrees east of Greenwich, and will extend in altitude from 0.0 to 120.0 kilometers. Values will be printed every 2.0 kilometers.

Figure C-3 shows two card decks used in the optimal procedure described in Section 5. The first deck interpolates meteorological data from the location of the meteorological profiles to the Shuttle trajectory. The keyword card CREATE causes the values resulting from this interpolation to be output on a new file in the same format as a LAIRS meteorological file.

The second deck uses this new file as input to the LAIRS Program and performs a differential correction on the data. Since all diurnal, semidiurnal, and latitude effects have already been included in the first run, they are turned off in this second run. A STATION keyword card is needed so that the system will recognize that the source of the data is a meteorological file, but the GMT field on the card will be ignored.

A sample job stream is shown in Figure C-4. The files used are:

- CARDS - the keyword card images (the deck shown in Figure C-1, for example)
- PERM1 - The permanent file
- ENT - The ENTREE file (the Best Estimate Trajectory (BET) file)
- MET1
- MET2 - The meteorological files produced by the preprocessor PREMET
- MET3
- KP - The Jacchia-Roberts geomagnetic index and solar flux file

All files beginning with "OBJ" are object modules.

The job streams required to run the decks in Figure C-3 are essentially the same as the job stream of Figure C-4. For the first deck of Figure C-3, however, an additional file (USEMET) is created during the run and must be saved after execution. This file is simply renamed and substituted for the meteorological files MET1, MET2, and MET3 in the run controlled by the second deck.

```
ENTREE          20.
UPMOD           3.0       1.0       0.0       0.0       0.0
LOWMOD          1.0       1.0       1.0       1.0       0.0
INTERPOL        2.0       0.0
END
ENTREE          20.
UPMOD           3.0       2.0       0.0       0.0       0.0
LOWMOD          2.0       2.0       0.0       0.0       0.0
INTERPOL        2.0       0.0
STATION         8.0
STATION         11.0
END
ENTREE          20.
UPMOD           3.0       2.0       0.0       0.0       0.0
LOWMOD          2.0       2.0       0.0       0.0       0.0
INTERPOL        2.0       2.0
STATION         8.0
STATION         11.0
END
ENTREE          20.
UPMOD           3.0       2.0       0.0       0.0       0.0
LOWMOD          4.0       2.0       1.0       1.0       0.0
STATION         8.0
STATION         11.0
END
ENTREE          20.
UPMOD           3.0       2.0       0.0       0.0       0.0
LOWMOD          4.0       2.0       1.0       1.0       0.0
STATION         8.0
STATION         11.0
DERIVE          0.5       2.0       30.0
END
ENTREE          20.
UPMOD           3.0       2.0       0.0       0.0       0.0
LOWMOD          4.0       2.0       1.0       1.0       0.0
DC
STATION         8.0
STATION         11.0
END
FIN
```

Figure C-1. LAIRS Benchmark Keyword Card Decks

```
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       1.0       0.0       0.0       0.0
LOWMOD              1.0       1.0       1.0       1.0       0.0
INTERPOL            2.0       0.0
END
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              2.0       2.0       0.0       0.0       0.0
INTERPOL            2.0       0.0
STATION             8.0
STATION             11.0
END
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              2.0       2.0       0.0       0.0       0.0
INTERPOL            2.0       2.0
STATION             8.0
STATION             11.0
END
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              4.0       2.0       1.0       1.0       0.0
STATION             8.0
STATION             11.0
END
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              4.0       2.0       1.0       1.0       0.0
STATION             8.0
STATION             11.0
DERIVE              0.5       2.0       30.0
END
LAP       800412.   100000.0  35.0      220.0     0.0       120.0     2.0
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              4.0       2.0       1.0       1.0       0.0
DC
STATION             8.0
STATION             11.0
END
FIN
```

Figure C-2. Sample LAIRS Deck Using LAP Option

```
ENTREE    810414.   12.0      60.0      95.00
UPMOD               2.0       2.0       1.0       1.0       0.0
LOWMOD              2.0       2.0       1.0       1.0       0.0
INTERPOL            2.0       1.0
STATION             17.083
STATION             17.2167
STATION             18.367
CREATE
END
FIN
ENTREE    810414.   00.00     00.0      000.0                         1000.
UPMOD               3.0       2.0       0.0       0.0       0.0
LOWMOD              4.0       2.0       0.0       0.0       0.0
MODREF              90.       68.       14.       4.
INTERPOL            2.0       1.0
DC
STATION             0.0
END
FIN
```

Figure C-3. Sample LAIRS Decks for Two-Step Modeling

```
/JOB
LAIRS,T200,CM140000.
USER,XXXXXXX.
CHARGE,XXXXXX,LRC.
GET,CARDS,PERM1,ENT.
GET,TAPE21=MET1.
GET,TAPE22=MET2.
GET,TAPE23=MET3.
GET,OBJJR,KP.
GET,OBJUTL,OBJWND.
GET,OBJCOM,OBJLR,OBJIO,OBJFIL,OBJINT.
GET,OBJPOL,OBJADJ,OBJDC.
MAP,OFF.
CTIME.
STIME.
ATTACH,FTNMLIB/UN=LIBRARY.
LDSET,LIB=FTNMLIB.
LOAD,OBJCOM,OBJLR,OBJIO,OBJJR,OBJFIL,OBJINT,OBJUTL,OBJWND.
LOAD,OBJPOL,OBJADJ,OBJDC.
EXECUTE.
DAYFILE,DAYFLE.
REPLACE,DAYFLE.
REWIND,OUT.
COPY,OUT.
REPLACE,OUT.
REWIND,USE.
REPLACE,USE.
EXIT.
DAYFILE,DAYFLE.
REPLACE,DAYFLE.
REWIND,OUT.
COPY,OUT.
REPLACE,OUT.
/
```

Figure C-4. Sample LAIRS Job Stream

APPENDIX D - FILE MAINTENANCE ROUTINE DESCRIPTIONS

This appendix contains descriptions of the preprocessor routines used for LAIRS file maintenance. These descriptions are in alphabetical order.

```
    FUNCTION FLUXAV (I1DAY, I81DAY)

PURPOSE:
    FLUXAV CALCULATES THE AVERAGE VALUE OF THE OBSERVED OTTAWA 2800 FLUX
    FOR AN 81 DAY PERIOD BEGINNING WITH I1DAY AND ENDING WITH I81DAY.

METHOD:
    1.  ADD THE FLUX VALUES FOR 81 DAYS AND STORE IN VARIABLE
        FLUXSM
    2.  DIVIDE FLUXSM BY 81 TO GET THE 81 DAY AVERAGE

ARGUMENT LIST:
 VARIABLE    TYPE      DESCRIPTION
 I1DAY        I        40 DAYS BEFORE THE DAY IN QUESTION
 I81DAY       I        40 DAYS AFTER THE DAY IN QUESTION

CALLING SUBROUTINE:   JRKP

SUBROUTINES CALLED:   NONE

COMMON BLOCK PARAMETERS:
 VARIABLE    TYPE      DESCRIPTION
 FLUX         R        OTTAWA 2800 FLUX NUMBER

PROGRAMMER/ANALYST:   A. K. KAPOOR, COMPUTER SCIENCES CORPORATION
```

Function FLUXAV

```
    PROGRAM JRKP(INPUT,OUTPUT,JRDATA,KPILE,TAPE5=JRDATA,TAPE75=KPILE)
PURPOSE:
    THIS PROGRAM BUILDS A JACCHIA-ROBERTS ATMOSPHERE FILE (FILE 75)
    IN GTDS DATA SET LAYOUT FORMAT.  CURRENT DIMENSIONS ARE FOR A
    FILE LENGTH OF ONE YEAR.

METHOD:
   1. READ YEAR, MONTH, DAY (IN PACKED FORM, I.E., YYMMDD), DAILY
      OBSERVED OTTAWA SOLAR FLUX AND THE THREE-HOURLY KP GEOMAGNETIC
      ACTIVITY INDEX.  I IS THE NUMBER OF DATA CARDS READ.
   2. CALCULATE THE MODIFIED JULIAN DATE (MJD) OF PACKED DATE
      JUST READ.
   3. CHECK IF DATA CARDS ARE IN ORDER, I.E., THAT DATES ARE
      INCREASING BY ONE AS EACH CARD IS READ.
   4. SET UP THE INFORMATION FOR THE HEADER RECORD. IDREC1 IS THE
      MJD OF THE FIRST DAY OF AVAILABLE DATA, N THE FILE.  IDREC1
      MUST BE A MULTIPLE OF 20.
   5. LOOP TO FINISH READING ALL THE INPUT CARDS.
   6. DETERMINE THE DATA RECORDS IN THE FILE  NREC .
   7. DETERMINE IF THE LAST RECORD IS A FULL 20 DAYS.
   8. DETERMINE THE MJD OF THE LAST DAY OF AVAILABLE DATA IN THE
      FILE (IDRECE) AND THE MJD OF THE LAST GOOD DATA POINT(LGD).
   9. WRITE THE HEADER RECORD.
  10. CALCULATE TC ARRAY, WHICH IS COMPOSED OF TWENTY DAYS OF NIGHT-
      TIME MINIMUM GLOBAL EXOSPHERIC TEMPERATURES, STARTING WITH DAY
      IT.  CALCULATE KP ARRAY, WHICH IS COMPOSED OF TWENTY-ONE DAYS OF
      PACKED KP3HR VALUES STARTING WITH DAY IT-1.
  11. ZERO THE KP AND TC ARRAYS SO THAT IF THE LAST DATA RECORD IS
      LESS THAN TWENTY DAYS, THE UNFILLED PORTION OF THE RECORD
      WILL BE PADDED WITH ZEROES.
  12. WRITE A DATA RECORD.  NRECWR COUNTS THE NUMBER OF RECORDS WRITTEN.
  13. UPDATE RECORD NUMBER AND IF EQUAL TO NREC, STOP.  IF NOT, THEN
      GO BACK TO POINT (10) AND CONTINUE PROCESSING.

ARGUMENT LIST:

CALLING SUBROUTINE:

SUBROUTINES CALLED:
                     FLUXAV

COMMON BLOCK PARAMETERS:
  VARIABLE   TYPE     DESCRIPTION
   FLUX        I      OTTAWA 2800 FLUX NUMBER

EXTERNAL DATA SETS USED:
  NAME    LUN      I/O OPERATION PERFORMED
  KP       75      WRITE THE FILE TO FILE 75

PROGRAMMER/ANALYST :  A. K. KAPOOR, COMPUTER SCIENCES CORPORATION
```

Program JRKP

```
    PROGRAM JRREAD (INPUT,OUTPUT,KPILE,TAPE75=KPILE)

PURPOSE:
    TO LIST THE KP FILE DATA SET BY EACH RECORD

METHOD:
    1.  READ THE HEADER RECORD.  NRECR COUNTS THE NUMBER OF RECORDS
        READ
    2.  PRINT THE CONTENTS OF HEADER RECORD
    3.  READ THE DATA RECORDS
    4.  PRINT THE DATA RECORDS
    5.  ADVANCE THE NRECR COUNTER AND GO BACK TO STEP 3.  IF LAST
        RECORD, THEN STOP.

ARGUMENT LIST: NONE

CALLING SUBROUTINES:


SUBROUTINES CALLED: OPENMS,READMS,CLOSMS

COMMON BLOCK PARAMETERS:  NONE

EXTERNAL DATA SETS USED:
  NAME     LUN    I/O OPERATIONS PERFORMED
  KP        75    READ ONLY

PROGRAMMER/ANALYST :  A. K. KAPOOR, COMPUTER SCIENCES CORPORATION
```

Program JRREAD

```
 PROGRAM PREMET(INPUT,OUTPUT,OUT1,MET1,MET2,MET3,
1 TAPE1=/80,TAPE8=OUT1,TAPE25=MET1,TAPE26=MET2,
2 TAPE27=MET3)
PURPOSE:
  TO READ ANY STRANGE METEOROLOGICAL DATA TAPE AND
  OUTPUT PROCESSED FILE(S) FOR LAIRS PROGRAM TO USE.
  THESE FILES ARE IN A FORMAT COMPATIBLE WITH THE
  LAIRS READ ROUTINE.

METHOD:
  1.  READ THE TAPE AND EXTRACT INFORMATION NEEDED BY
      LAIRS:  SUCH AS  NUMBER OF FILES (PROFILES ON TAPE
              NUMBER OF POINTS/PROFILE
              STARTING POINT/PROFILE
              END POINT/PROFILE

  2.  READ THE DATA AND OUTPUT AN INVERTED PROFILE FOR
      EACH PROFILE (FILE)

  3.  CONVERT THE DATA TO METRIC UNITS

  4.  WRITE A SINGLE HEADER RECORD WITH THE INFORMATION
      STATED IN POINT 1
      THEN WRITE THE NUMBER OF FILES DEPENDING ON THE
      NUMBER OF PROFILES PROVIDED ON THE ORIGINAL TAPE

ARGUMENT LIST:  NONE

CALLING ROUTINES:  NONE

SUBROUTINES CALLED:  NONE

COMMON BLOCK PARAMETERS USED:  NONE

EXTERNAL DATA SETS USED:

NAME       FILE #            DESCRIPTION
 1         /80          ORIGINAL TAPE FROM LARC
25         MET1         FIRST FILE WITH HEADER
26         MET2         SECOND FILE
27         MET3         THIRD FILE  (PROFILE)

PROGRAMMER/ANALYST :  A. K. KAPOOR , COMPUTER SCIENCES CORPORATION
```

Program PREMET

APPENDIX E - DIFFERENTIAL CORRECTION NOISE ANALYSIS

A series of tests of the differential correction process using simulated data was conducted to determine the response of the program to various levels of random noise. A non-DC polynomial fitting run was used with default CIRA data to produce a simulated meteorological file via the CREATE keyword option. This file was used as input to a modified version of LAIRS which, prior to fitting, added a specified amount of random noise to the simulated data. The LARC library routine URAN, which returns a uniformly distributed random number between 0 and 1, was used in this process. The random number was shifted to lie in the interval between -0.5 and 0.5 and scaled by a factor supplied in each test to yield noise with average amplitudes ranging up to 40 percent of the values of the parameters on the file.

It was found that, for relatively low noise levels, the differential correction process consistently yielded excellent results, with the estimated parameters often being within a few percent of the known values even when the noise amplitudes reached 20 or 25 percent. For larger noise amplitudes, the results were generally good although, of course, larger variations in the values of the estimated parameters tended to accompany these larger noise amplitudes. In all test cases, the results were well within the range of acceptability for the noise levels and number of data points used (generally 30 to 50 points per segment).

The LAIRS differential correction process proved to be very stable in all the tests. High levels of random noise did not result in excessive editing of data points or in runs that would not converge in a few iterations.

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15. Supplementary Notes

Langley Technical Monitor: Joseph M. Price
Final Report

16. Abstract

This document presents the user's guide, system description, and mathematical specifications for the Langley Atmospheric Information Retrieval System (LAIRS). It also includes a description of an optimal procedure for operational use of LAIRS. The primary objective of the LAIRS Program is to make it possible to obtain accurate estimates of atmospheric pressure, density, temperature, and winds along Shuttle reentry trajectories for use in postflight data reduction.

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